THE PRESENT STATUS

OF

LITARY AËRONAUT

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Major Signal Corps, U. S. Army

THE PRESENT STATUS OF MI
AËRONAUTICS

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THE PRESENT STATUS O
AËRONAUTICS

BY DR. GEORGE O. SQUI
MAJOR, SIGNAL CORPS, U. S. A
Non-Member

It is a matter of first significance that T
Mechanical Engineers, composed of a body
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10 The Aëronautical Division of the Office of the
Officer of the Army was organized on July 1, 1907, and
tical Board of the Signal Corps was appointed in July
year for conducting tests of dirigible balloons and aëro
existing contracts.

11 It should be stated that the mention of partic
dirigible balloons and aëroplanes in this paper must not
as an official indorsement of these particular machines, n
to mention other types be construed to indicate a la
recognition of the merits of the latter. In the case o
Brothers, however, it is desired to associate the Signal
Army publicly and officially with the present universa
of their work in advancing the Science and Art of Avia
results have been due to the persistence, daring, and i

a Lighter-than-air types:
Free balloons, dirigible balloons or airships

b Heavier-than-air types:
Aëroplanes, orthopters, helicopters, etc.

13 It should be remarked, however, that these two g
classes exhibit a growing tendency to overlap each other.
example, the latest dirigible balloons are partly operated by
of aëroplane surfaces, and are also often balanced so as to be sl
heavier than the air in which they move, employing the pro
thrust and rudder surfaces to control the altitude.

I. AËROSTATION

14 Captive and free balloons, with the necessary apparatu
devices for operating the same, have been for many years cons
an essential part of the military establishment of every firs
Power. They played a conspicuous part in the siege of Pari
were often valuable in our own Civil War. The constructio
operation of aërostats are too well understood to need further
tion here.

Successful Military Dirigible Balloons

FRANCE

15 Two types of dirigible balloons have been used in the F
Army; first the *Patrie*, and second the *Ville de Paris*.

16 The *Patrie* was developed by Julliot, an engineer employ
the Lebaudy Brothers at their sugar refinery in Paris. A hist
his work beginning in 1896 is fully given in *La Conquête de l'Ai*

Renard's dirigible, built and operated in France in 18
general shape and proportions being found in the *Vill*

18 The first Lebaudy was pointed at the rear, whicl
admitted to be the proper shape for the least resistance,
tain stability it was found necessary to put a horizonta
plane there, so that it had to be made an ellipsoid of revo
attachment for these planes.

19 The ballonet for air had a capacity of 22 958 cu.
of the total volume. This is calculated to permit reachi
about one mile and to be able to return to the earth, ke
bag always rigid. To descend from a height of one mile,
released by the valve, then air pumped into the ballone
gas bag rigid, these two operations being carried on alte
reaching the ground from the height of one mile the air w
middle of the lower part of the gas bag and would not
the ballonet. To prevent the air from rolling from on
other when the airship pitches, thus producing instability
was divided into three compartments by impermeabl
tions. Numerous small holes were pierced in these parti
which the air finally reached the two end compartments

20 In September, 1907, the *Patrie* was enlarged by
by the addition of a cylindrical section at the maxim
increasing the length but not the maximum diameter.

21 The *gas bag* is cut in panels; the material is a rubb
by the Continental Tire Company at Hanover, Germa
sists of four layers arranged as follows:

W
per s

a Outer layer of cotton cloth covered with
lead chromate....................

leaking of the gas. The inner layer of rubber is merely to prevent deterioration of the cloth by impurities in the gas. This material has the warp of the two layers of cotton cloth running in the same direction and is called straight thread. The material in the ballonet weighs only about 7¾ oz. per sq. yd. and has a strength of about 336 lb. per running foot. When the *Patrie* was enlarged in September, 1907, the specifications for the material allowed a maximum weight of 10 oz. per sq. yd., a minimum strength of 907 lb. per running foot, and a loss of 5.1 cu. in. of hydrogen per square yard in twenty-four hours at a pressure of 1.18 in. of water. Bands of cloth are pasted over the seams inside and out with a solution of rubber to prevent leaking through the stitches.

23 *Suspension.* One of the characteristics of the *Patrie* is the "short" suspension. The weight of the car is distributed over only about 70 ft. of the length of the gas bag. To do this, an elliptical shaped frame of nickel steel tubes is attached to the bottom of the gas bag; steel cables run from this down to the car. A small hemp net is attached to the gas bag by means of short wooden cross pieces or toggles which are let into holes in a strong canvas band which is sewed directly on the gas bag. The metal frame, or platform, is attached to this net by means of toggles, so that it can be quickly removed in dismounting the airship for transportation. The frame can also be taken apart. 28 steel cables about 0.2 in. in diameter run from the frame down to the car, and are arranged in triangles. Due to the impossibility of deforming a triangle, rigidity is maintained between the car and gas bag.

24 The objection to the "short" suspension of the *Patrie* is the deformation of the gas bag. A distinct curve can be seen in the middle.

25 *The Car.* The car is made of nickel steel tubes (12 per cent nickel). This metal gives the greatest strength for minimum weight. The car is boat-shaped, about 16 ft. long, about 5 ft. wide, and 2½ ft. high. About 11 ft. separate the car from the gas bag. To prevent any chance of the fire from the engine communicating with the hydrogen, the steel framework under the gas bag is covered with a non-combustible material.

26 The pilot stands at the front of the car, the engine is in the middle, the engineer at the rear. Provision is made for mounting a telephotographic apparatus, and for a 100-candle-power acetylene search-light. A strong pyramidal structure of steel is built under the car, pointing downward. In landing the point comes to the ground

first and this protects the car, and especially the propellers, from being damaged. The car is covered to reduce air resistance. It is so low, however, that part of the equipment and most of the bodies of those inside are exposed, so that the total resistance of the car is large.

27 *The Motor.* The first Lebaudy had a 40 h. p. Daimler-Mercedes benzine motor. The *Patrie* was driven by a 60 to 70 h.p., 4-cylinder Panhard and Levassor benzine motor, making 1000 r.p.m.

28 *The Propellers.* There are two steel propellers $8\frac{1}{2}$ ft. in diameter (two blades each) placed at each side of the engine, thus giving the shortest and most economical transmission. To avoid any tendency to twist the car, the propellers turn in opposite directions. They are "high speed," making 1000 to 1200 r.p.m.

29 The gasolene tank is placed under the car inside the pyramidal frame. The gasoline is forced up to the motor by air compression. The exhaust is under the rear of the car pointing down and is covered with a metal gauze to prevent flames coming out. The fan which drives the air into the ballonet is run by the motor, but a dynamo is also provided so that the fan can always be kept running even if the motor stops. This is very essential as the pressure must be maintained inside the gas bag so that the latter will remain rigid and keep its form. There are five valves in all, part automatic and part both automatic and also controlled from the car with cords. The valves in the ballonet open automatically at less pressure than the gas valves, so that when the gas expands all the air is driven out of the ballonet before there is any loss of gas. The ballonet valves open at a pressure of about 0.78 in. of water, the gas valves at about 2 in.

30 *Stability.* Vertical stability is maintained by means of fixed horizontal planes. One having a surface of 150 sq. ft. is attached at the rear of the gas bag, and due to its distance from the center of gravity is very efficient. The elliptical frame attached under the gas bag has an area of 1 055 sq. ft. but due to its proximity to the center of gravity, has little effect on the stability. Just behind the elliptical frame is an arrangement similar to the feathering on an arrow. It consists of a horizontal plane of 150 sq. ft., and a vertical plane of 113 sq. ft. To maintain horizontal stability, that is, to enable the airship to move forward in a straight line without veering to the sides, fixed vertical planes are used. One runs from the center to the rear of the elliptical frame and has an area of 108 sq. ft.

31 In addition to the vertical surface of 113 sq. ft. at the rear of the elliptical frame, there is a fixed plane of 150 sq. ft. at the rear of

the gas bag. To fasten the two perpendicular planes at the rear of the gas bag, cloth flaps are sewed directly on the gas bag. Nickel steel tubes are placed in the flaps which are then laced over the tubes. With these tubes as a base, a light tube and wire framework is attached and water-proof cloth laced on this framework. Additional braces run from one surface to the other and from each surface to the gas bag. The rudder is at the rear under the gas bag. It has about 150 sq. ft. and is balanced.

32 A movable horizontal plane near the center of gravity, above the car, is used to produce rising or descending motion, or to prevent an involuntary rising or falling of the airship due to expansion or contraction of the gas or to other causes. After the adoption of this movable horizontal plane, the loss of gas and ballast was reduced to a minimum. Ballast is carried in 10 and 20 lb. sand bags. A pipe runs through the bottom of the car from which the ballast is thrown.

33 There are two long guide ropes, one attached at the front of the elliptical frame and the other on the car. On landing, the one in front is seized first so as to hold the airship with the head to the wind. The motor may then be stopped and the descent made by pulling down on both guide ropes. A heavy rope, 22 ft. long, weighing 110 lb. is attached on the end of a 164 ft. guide rope. This can be dropped out on landing to prevent coming to the ground too rapidly. The equipment of the car includes a "siren," speaking trumpet, carrier pigeons, iron pins and a rope for anchoring the airship, reserve supply of fuel and water, and fire extinguisher.

34 After being enlarged in September, 1907, the *Patrie* made a number of long trips at an altitude of 2 500 to 3 000 ft. In November 1907, she went from Paris to Verdun, near the German frontier, a distance of about 175 miles, in about 7 hours, carrying four persons. This trip was made in a light wind blowing from the northeast. Her course was east, so that the wind was unfavorable. On Friday, November 29, 1907, during a flight near Verdun, the motor stopped due to difficulty with the carburetter. The airship drifted with the wind to a village about 10 miles away where she was safely landed. The carburetter was repaired on the 30th. Soon after, a strong wind came up and tore loose some of the iron pickets with which it was anchored. This allowed the airship to swing broadside to the wind; it then tilted over on the side far enough to let some of the ballast bags fall out. The 150 or 200 soldiers who were holding the ropes were pulled along the ground until directed by the officer in charge to let go. After being released, it rose and was carried by the wind across the

north of France, the English Channel, and into the north of Ireland. It struck the earth there, breaking off one of the propellers and then drifted out to sea.

THE REPUBLIQUE

35 This is the latest of the French military dirigible balloons, and differs but slightly from its predecessor, the *Patrie*. The volume has been increased by about 2 000 cu. ft. The length has been reduced to 200 ft. and the maximum diameter increased to 35½ ft. The shape of the gas bag accounts for the 2 000 additional cubic feet of volume. The motor and propellers are as in the *Patrie*. The total lifting capacity is 9 000 lb., of which 2 700 lb. are available for passengers, fuel, ballast, instruments, etc. Its best performance was a 125-mile flight made in 6½ hours against an unfavorable wind.

36 The material for the gas bag of the new airship was furnished by the Continental Tire Company. It is made up as follows:

	Weight oz. per square yard
Outer yellow cotton layer	3.25
Layer of vulcanized rubber	3.25
Layer of cotton cloth	3.25
Inner layer of rubber	0.73
Total weight	10.48

37 It is interesting to note the changes which this type has undergone since the first one was built. The *Jaune*, constructed in 1902-03, was pointed at the rear and had no stability plane there; later it was rounded off at the rear and a fixed horizontal plane attached. Finally a fixed vertical plane was added. The gas bag has been increased in capacity from 80 670 cu. ft. to about 131 000 cu. ft. The manufacturers have been able to increase the strength of the material of which the gas bag is made, without materially increasing the weight. The rudder has been altered somewhat in form. It was first pivoted on its front edge, but later on a vertical axis, somewhat to the rear of this edge. With the increase in size, has come an increase in carrying capacity and consequently a greater speed and more widely extended field of action.

VILLE DE PARIS

38 This airship was constructed for Mr. Deutsch de la Meurthe, of Paris, who has done a great deal to encourage aërial navigation. The

first *Ville de Paris* was built in 1902, on plans drawn by Tatin, a French aëronautical engineer. It was not a success. Its successor was built in 1906, on plans of Surcouf, an aëronautical engineer and balloon builder. The gas bag was built at his works in Billancourt, the mechanical part at the Voisin shop, also in Billancourt. The plans are based on those of Colonel Renard's airship, the *France*, built in 1884, and the *Ville de Paris* resembles the older airship in many particulars. In September, 1907, Mr. Deutsch offered the use of his airship to the French Government. The offer was accepted, but delivery was not to be made except in case of war or emergency. When the *Patrie* was lost in November, 1907, the military authorities immediately took over the Deutsch airship.

39 *Gas Bag.* The gas bag is 200 ft. long for a maximum diameter of 34½ ft., giving a length of about 6 diameters, as in the *France* and the *Patrie.* Volume 112 847 cu. ft. maximum diameter at about ⅗ of the distance from the front, approximately, as in the *Patrie.* The middle section is cylindrical with conical sections in front and rear. At the extreme rear is a cylindrical section with eight smaller cylinders attached to it. The ballonet has a volume of 21 192 cu. ft., or about $\frac{1}{5}$ of the whole volume, the same proportion found in the *Patrie.* The ballonet is divided into three compartments from front to rear. The division walls are of permeable cloth, and are not fastened to the bottom so that when the middle compartment fills with air, and the ballonet rises, the division walls are lifted up from the bottom of the gas bag, and there is free communication between the three compartments. The gas bag is made up of a series of strips perpendicular to a meridian line. These strips run around the bag, their ends meeting on the under meridian. This is known as the "brachistode" method of cutting out the material, and has the advantage of bringing the seams parallel to the line of greatest tension. They are therefore more likely to remain tight and not allow the escape of gas. The disadvantage lies in the fact that there is a loss of 33⅓ per cent of material in cutting. The material was furnished by the Continental Tire Company, and has approximately the same tensile strength and weight as that used in the *Patrie.* It differs from the other in one important feature—it is diagonal-thread, that is, the warp of the outer layer of cotton cloth makes an angle of 45 deg. with the warp of the inner layer of cotton cloth. The result is to localize a rip or tear in the material. A tear in the straight thread material will continue along the warp, or the weave, until it reaches a seam.

40 *Valves.* There are five in all, made of steel, about fourteen inches in diameter; one on the top connected to the car by a cord, operated by hand only; two near the rear underneath. These are automatic but can be operated by hand from the car. Two ballonet valves directly under the middle are automatic and are also operated from the car by hand. The ballonet valves open automatically at a pressure of $\frac{3}{4}$ in. of water, the gas valves open at a higher pressure.

41 *Suspension.* This airship has the "long" suspension. That is, the weight is distributed along practically the entire length of the gas bag. A doubled band of heavy canvas is sewn with six rows of stitches along the side of the gas bag. Hemp ropes running into steel cables transmit most of the weight of the car to these two canvas bands and thus to the gas bag. On both sides and below these first bands are two more. Lines run from these to points half way between the gas bag and the car, then radiate from these points to different points of attachment on the car. This gives the triangular or non-deformable system of suspension, which is necessary in order to have the car and gas bag rigidly attached to each other. With this "long" suspension, the *Ville de Paris* does not have the deformation so noticeable in the gas bag of the *Patrie.*

42 *The Car.* This is in the form of a trestle. It is built of wood with aluminum joints and 0.12 in. wire tension members. It is 115 ft. long, nearly 7 ft. high at the middle, and a little over $5\frac{1}{2}$ ft. wide at the middle. It weighs 660 lb. and is considered unnecessarily large and heavy The engine and engineer are well to the front, the aëronaut with steering wheels is about at the center of gravity.

43 *Motor.* The motor is a 70 to 75 h.p. "Argus," and is exceptionally heavy.

44 *Propeller.* The propeller is placed at the front end of the car. It thus has the advantage of working in undisturbed air; the disadvantage is the long transmission and difficulty in attaching the propeller rigidly. It has two blades and is 19.68 ft. long with a pitch of 26.24 ft. The blades are of cedar with a steel arm. The propeller makes a maximum of 250 turns per minute when the engine is making 900 rev. Its great diameter and width compensate for its small speed.

45 *Stability.* This is maintained entirely by the cylinders at the rear. Counting the larger one to which the smaller ones are attached, there are five, arranged side by side corresponding to the horizontal planes of the *Patrie,* and five vertical ones corresponding to the *Patrie's* vertical planes. The volume of the small cylinders is so calculated

that the gas in them is just sufficient to lift their weight, so they neither increase or decrease the ascensional force of the whole. The horizontal projection of these cylinders is 1076 sq. ft. The center of this projection is 72 ft. from the center of gravity of the gas. The great objection to this method of obtaining stability, is the air resistance due to these cylinders, and consequent loss of speed. The stability of the *Ville de Paris* in a vertical plane is said to be superior to that of the *Patrie,* due to the fact that the stability planes of the latter do not always remain rigid. The independent velocity of the *Ville de Paris* probably never exceeded 25 miles an hour.

46 *The Rudder.* The rudder has a double surface of 150 sq. ft. placed at the rear end of the car, 72 ft. from the center of gravity. It is not balanced, but is inclined slightly to the rear so that its weight would make it point directly to the rear if the steering gear should break. Two pairs of movable horizontal planes, one at the rear of the car having 43 sq. ft., and one at the center of gravity (as on the *Patrie*) having 86 sq. ft. serve to drive the airship up or down without losing gas or ballast.

47 *Guide Ropes.* A 400 ft. guide rope is attached at the front end of the car. A 230 ft. guide rope is attached to the car at the center of gravity.

48 About thirty men are required to maneuver the *Ville de Paris* on the ground. The pilot has three steering wheels, one for the rudder and two for the movable horizontal planes. The instruments used are an aneroid barometer, a registering barometer giving heights up to 1600 ft. and an ordinary dynamometer which can be connected either with the gas bag or ballonet by turning a valve. A double column of water is also connected to the tube to act as a check on the dynamometer. Due to the vibration of the car caused by the motor, these instruments are suspended by rubber attachments. Even with this arrangement, it is necessary to steady the aneroid barometer with the hand in order to read it. The vibration prevents the use of the statoscope.

ENGLAND

MILITARY DIRIGIBLE NO. 1

49 The gas bag of this airship was built about five years ago by Colonel Templar, formerly in command of the aëronautical establishment at Aldershot. His successor, Colonel Capper built the mechanical part during the spring and summer of 1907, with the assistance of Mr.

S. F. Cody, a mechanical engineer. It was operated by Colonel Capper as pilot, with Mr. Cody in charge of the engine. Several ascents were made at Aldershot. In October 1907, they made a trip from Aldershot to London, a distance of about 40 miles, landing at the Crystal Palace. For several days the rain and wind prevented attempting the return journey. On October 10 a strong wind threatened to carry away the airship, so the gas bag was cut open by the sergeant in charge.

50 *Gas Bag.* This is made of eight layers of gold beater's skin. It is cylindrical in shape with spherical ends. Volume 84 768 cu. ft.; length 111½ ft.; maximum diameter, 31½ ft. The elongation therefore is only about 3⅝. There is no ballonet, but due to the toughness of the gold beater's skin, a much higher pressure can safely be maintained than in gas bags of rubber cloth. Without a ballonet, however, it would not be safe to rise to the heights reached by the *Patrie.*

51 *Valves.* The valves are made of aluminum and are about 12 in. in diameter.

52 *Suspension.* In this airship they have succeeded in obtaining a "long" suspension with a short boat-shaped car, a combination very much to be desired, as it distributes the weight over the entire length of the gas bag and gives the best form of car for purposes of observation and for maneuvering on the ground. To obtain this combination they have had to construct a very heavy steel framework which cuts down materially the carrying capacity, and moreover, this framework adds greatly to the air resistance. This is the only airship in Europe having a net work to support the car. In addition, four silk bands are passed over the gas bag and wires run from their extremities down to the steel frame. This steel frame is in two tiers; the upper is rectangular in cross-section and supports the rudder and planes; the lower part is triangular in cross-section and supports the car. The joints are aluminum.

53 *The Car.* This is of steel and is about thirty feet long. To reduce air resistance, the car is covered with cloth.

54 *Motor.* A 40 to 50 h.p. 8-cylinder Antoinette motor is used. It is set up on top of the car. The benzine tanks are supported above in the framework. Gravity feed is used.

55 *Propellers.* There are two propellers, one on each side, with two blades each, as in the *Patrie.* They are made of aluminum, 10 ft. in diameter, and make 700 r.p.m. The transmission is by belt.

56 *Stability.* This is maintained by means of planes. At the extreme rear is a large fixed horizontal plane. In front of this is a pair of

hinged horizontal planes. Under this is the hexagonal shaped rudder. It is balanced. Two pairs of movable horizontal planes, 8 ft. by 4 ft., each placed at the front serve to guide the airship up and down, as in the *Patrie* and *Ville de Paris.* These planes have additional inclined surfaces which are intended to increase the stability in a vertical plane. All these planes, both fixed and movable, are constructed like kites, of silk stretched on bamboo frames. The guide rope is 150 ft. long. Speed attained, about 16 miles per hour. This airship with a few improvements added has been in operation the past few months. The steel framework connecting the gas bag to the car, is now entirely covered with canvas, which must reduce the resistance of the air very materially. The canvas covering, enclosing the entire bag, serves as a reinforcement to the latter and at the same time gives attachment to the suspension underneath. It is reported that a speed of 20 miles an hour has been attained with the reconstructed airship.

57 A pyramidal construction similar to that on the *Patrie* has been built under the center of the car to protect the car and propellers on landing. A single movable horizontal plane placed at the front end of the car and operated by the pilot, controls the vertical motion.

GERMANY

58 Three different types of airships are being developed in Germany. The *Gross* is the design of Major Von Gross, who commands the Balloon Battalion at Tegel near Berlin. The *Parseval* is being developed by Major Von Parseval, a retired German Officer, and the *Zeppelin* is the design of Count Zeppelin, also a retired officer of the German Army.

THE GROSS

59 The first airship of this type made its first ascension on July 23, 1907. The mechanical part was built at Siemen's Electrical Works in Berlin; the gas bag by the Riedinger firm in Augsburg.

60 *Gas Bag.* The gas bag is made of rubber cloth furnished by the Continental Tire Company similar to that used in the *Ville de Paris.* It is diagonal-thread, but there is no inner layer of rubber, as they do not fear damage from impurities in the hydrogen gas. Length, 131¼ ft.; maximum diameter, about 39⅓ ft.; volume 63 576 cu. ft.; the elongation is about 3⅓. The form is cylindrical with spherical cones at the ends, the whole being symmetrical.

61 *Suspension.* The suspension is practically the same as that of the *Patrie.* A steel and aluminum frame is attached to the lower part of the gas bag, and the car is suspended on this by steel cables. The objection to this system is even more apparent in the *Gross* than in the *Patrie.* A marked dip along the upper meridian of the gas bag shows plainly the deformation.

62 *The Car.* The car is boat-shaped like that of the *Patrie.* It is suspended thirteen feet below the gas bag.

63 *Motor.* The motor is a 20 to 24 h.p., 4-cylinder "Daimler-Mercedes."

64 *Propellers.* There are two propellers $8\frac{2}{10}$ ft. in diameter, each having two blades. They are placed one on each side, but well up under the gas bag near the center of resistance. The transmission is by belt. The propellers make 800 r.p.m.

65 *Stability.* The same system, with planes, is used in the *Von Gross* as in the *Patric,* but it is not nearly so well developed. At the rear of the rigid frame attached to the gas bag, are two fixed horizontal planes, one on each side. A fixed vertical plane runs down from between these horizontal planes, and is terminated at the rear by the rudder. A fixed horizontal plane is attached on the rear of the gas bag as in the *Patrie.* The method of attachment is the same, but the plane is put on before inflation in the Gross airship, afterwards in the *Patrie.* The stability of the Gross airship in a vertical plane is reported to be very good, but it is said to veer considerably in attempting to steer a straight course.

66 The many points of resemblance between this dirigible and the Lebaudy type are worthy of notice. The suspension or means of maintaining stability, and the disposition for driving are in general the same. As first built, the *Gross* had a volume of 14 128 cu. ft. less than at present, and there was no horizontal plane at the rear of the gas bag. Its maximum speed is probably fifteen miles per hour. As a result of his experiments of 1907, Major Von Gross has this year produced a perfected airship built on the same lines as his first, but with greatly increased volume and dimensions. The latest one has a volume of 170 000 cu. ft., is driven by two 75 h.p. Daimler motors, and has a speed of 27 miles per hour.

67 On September 11 of this year, the Gross airship left Berlin at 10.25 p.m., carrying four passengers, and returned the next day at 11.30 a.m., having covered 176 miles in the period of a little over 13 hours. This is the longest trip, both in point of time and distance ever made by any airship returning to the starting point.

THE PARSEVAL

68 The Parseval airship is owned and controlled by the Society for the Study of Motor Balloons. This organization, composed of capitalists, was formed practically at the command of the Emperor who is very much interested in aërial navigation. The Society has a capital of 1 000 000 marks, owns the Parseval patents and is ready to construct airships of the Von Parseval type. The present airship was constructed by the Riedinger firm at Augsburg, and is operated from the balloon house of this Society at Tegel, adjoining the military balloon house.

69 The gas bag is similar in construction to that of the "*Drachen*" balloon, used by the army for captive work. Volume, 113 000 cu. ft., length 190 ft., maximum diameter $30\frac{1}{2}$ ft. It is cylindrical in shape, rounded at the front end and pointed at the rear. The material was furnished by the Continental Tire Company. It is diagonal-thread, weighing about $11\frac{2}{10}$ oz. per sq. yd. and having a strength of about 940 lb. per running foot. Its inner surface is covered with a layer of rubber.

70 *Ballonets.* There are two ballonets, one at each end, each having a capacity of 10 596 cu. ft. The material in the ballonet weighs about $8\frac{1}{4}$ oz. per sq. yd., the cotton layers being lighter than in the material for the gas bag. Air is pumped into the rear ballonet before leaving the ground, so that the airship operates with the front end inclined upward. The air striking underneath, exerts an upward pressure, as on an aëroplane, and thus adds to its lifting capacity. Air is pumped into the ballonets from a fan operated by the motor. A complex valve just under the middle of the gas bag, enables the engineer to drive air into either, or both ballonets. The valves also act automatically and release air from the ballonets at a pressure of about 0.9 in. of water.

71 In the middle of the top of the gas bag, is a valve for releasthe gas. It can be operated from the car, and opens automatically at a pressure of about 2 in. of water. Near the two ends and on opposite sides, are two rip strips controlled from the car by cords.

72 *Suspension.* The suspension is one of the characteristics of the airship, and is protected by patents. The car has four trolleys, two on each side, which run on two steel cables. The car can run backwards and forwards on these cables, thus changing its position with relation to the gas bag. This is called "loose" suspension. Its object is to allow the car to take up, automatically, variations in

thrust due to the motor, and variations in resistance due to the air. Ramifications of hemp rope from these steel cables are sewn onto a canvas strip which in turn is sewn onto the gas bag. This part of the suspension is the same as in the Drachen balloon. The weight is distributed over the entire length of the gas bag.

73 *The Car.* The car is 16.4 ft. long and is built of steel tubes and wire. It is large enough to hold the motor and three men, though four or five may be taken.

74 *Motor.* The motor is a 110 h.p. Daimler-Mercedes. Sufficient gasolene is carried for a run of 12 hours.

75 *Propeller.* The propeller, like the suspension, is peculiar to this airship and is protected by patents. It has four cloth blades which hang limp when not turning. When the motor is running, these blades, which are carefully weighted with lead at certain points, assume the proper position due to the various forces acting. The diameter is 13¾ ft. The propeller is placed above the rear of the car near the center of resistance. Shaft transmission is used. The propeller makes 500 r.p.m. to 1000 of the motor. There is a space of 6½ ft. from the propeller blades to the gas bag, the bottom of the car being about 30 ft. from the gas bag. This propeller has the advantage of being very light. Its position, so far from the engine, necessarily incurs a great loss of power in transmission.

76 The steering wheel at the front of the car, has a spring device for locking it in any position.

77 The 1908 model of this airship was constructed for the purpose of selling it to the Government. Among other requirements is a 12 hour flight without landing, and a sufficient speed to maneuver against a 22-mile wind. A third and larger airship of this type is now under construction.

THE ZEPPELIN

78 The Zeppelin airship, of which there have been four, differs from all others in that the envelope is rigid. Sixteen separate gas bags are contained in an aluminum alloy framework having 16 sides, covered with a cotton and rubber fabric. The pressure of the air is taken up by this framework instead of by the gas bags. The gas bags are not entirely filled, thus leaving room for expansion.

79 The rigid frame is 446 ft. long, 42½ ft. in diameter, and has ogival-shaped ends. It is braced about every 45 ft. by a number of rods crossing near the center, giving a cross section resembling a bicycle wheel. Vertical braces are placed at intervals the entire

length of the frame. The 16 gas bags are completely separated from each other by partitions of sheet aluminum. Under the framework is a triangular truss running nearly the entire length, the sides of the triangle being about 8 ft. The total volume of the gas bags is 460 000 cu. ft. which gives a gross lift of about 32 000 lb.

80 *Suspension.* The two cars are rigidly attached directly to the frame of the envelope, and a very short distance below it.

81 *Cars.* The two cars are built like boats. They are about 20 ft. long, 6 ft. wide, 3½ ft. high; are placed about 100 ft. from each end and are made of the same aluminum alloy. To land the airship, it is lowered until the cars float on the water, when it can be towed like a ship. A third car is built into the keel directly under the center of the framework, and is for passengers only.

82 *Motors.* The power is furnished by two 110 h.p. Daimler-Mercedes motors, one placed on each car. Each weighs about 550 lb.; sufficient fuel for a 60 hours run can be carried.

83 *Propellers.* A pair of three-bladed metal propellers about 15 ft. in diameter is placed opposite each car, firmly attached to the frame of the envelope at the height of the center of resistance where they are most efficient.

84 *Stability.* In addition to the long V-shaped keel under the rigid frame, on each side at the rear of the frame are two nearly horizontal planes, while above and below the rear end are vertical fins.

85 *Steering.* A large vertical rudder is attached at the extreme end of the rigid frame, and an additional one is placed between each set of horizontal planes on the sides. For vertical steering, there are four sets of movable horizontal planes placed near the ends of the rigid frame, about the height of the propellers. Each set consists of four horizontal planes placed one above the other and connected with rods, so that they work on the principle of a shutter. These horizontal rudders serve another very important purpose, due to the reaction of the air. When these planes are set at an angle of 15 deg. and the airship is making a speed of 35 miles per hour, an upward pressure of over 1700 lb. is exerted, and consequently all the gas in one compartment could escape and yet by the manipulation of these planes, the airship could return safely to its starting point.

86 Its best performances were two long trips made during the past summer. The first, July 4th, lasted exactly twelve hours, during which time it covered a distance of 235 miles, crossing the mountains to Lucerne and Zurich, and returning to the balloon house at Fried-

richshafen on Lake Constance. The average speed on this trip was 32 miles per hour. On August 4 this airship attempted a 24-hour flight, which was one of the requirements made for its acceptance by the Government. It left Friedrichshafen in the morning with the intention of following the Rhine as far Mainz, and then returning to its starting point straight across the country. A stop of 4 hours and 30 minutes was made in the afternoon of the first day on the Rhine, to repair the engine. On the return, a second stop was found necessary near Stuttgart, due to difficulties with the motors and the loss of gas. While anchored to the ground a storm came up, and broke loose the anchorages; and as the balloon rose in the air it exploded and took fire, due to causes which have never been actually determined and published, and fell to the ground, resulting in its complete destruction. On this journey, which lasted in all 31 hours and 15 minutes, the airship was in the air 20 hours and 45 minutes, and covered a total distance of 378 miles.

87 The patriotism of the German nation was aroused. Subscriptions were immediately opened and in a short space of time $1 000 000 had been raised. A Zeppelin Society was formed to direct the expenditure of this fund. $85 000 has been expended for land near Friedrichshafen; shops are being constructed and it has been announced that within one year, the construction of 8 airships of the Zeppelin type will be completed. Recently the Crown Prince of Germany made a trip in the *Zeppelin No. 3*, which had been called back into service, and within a very few days the Emperor of Germany visited Friedrichshafen for the purpose of seeing the airship in flight. He decorated Count Zeppelin with the Order of the Black Eagle. German patriotism and enthusiasm has gone further, and the "German Association for an Aërial Fleet" has been organized in sections throughout the country. It announces its intention of building fifty garages (hangars) for housing airships.

UNITED STATES

SIGNAL CORPS DIRIGIBLE NO. 1

88 Due to lack of funds, the United States Government has not been able to undertake the construction of an airship sufficiently large and powerful to compete with those of European nations. However, specifications were sent out last January for an airship not over 120 ft. long and capable of making 20 miles per hour. Contract

was awarded to Capt. Thomas S. Baldwin, who delivered an airship last August to the Signal Corps, the description of which follows:

89 *Gas Bag.* The gas bag is spindle shaped, 96 ft. long, maximum diameter 19 ft. 6 in. with a volume of 20 000 cu. ft. A ballonet for air is provided inside the gas bag, and has a volume of 2 800 cu. ft. The material for the gas bag is made of two layers of Japanese silk, with a layer of vulcanized rubber between.

90 *Car.* The car is made of spruce, and is 66 ft. long, 2½ ft. wide, and 2½ ft. high.

91 *Motor.* The motor is a 20 h.p. water-cooled Curtiss make.

92 *Propeller.* The propeller is at the front end of the car, and is connected to the engine by a steel shaft. It is built up of spruce, has a diameter of 10 ft. 8 in. with a pitch of 11 ft., and turns at the rate of 450 r.p.m. A fixed vertical surface is provided at the rear end of the car to minimize veering, and a horizontal surface attached to the vertical rudder at the rear tends to minimize pitching. A double horizontal surface controlled by a lever and attached to the car in front of the engine, serves to control the vertical motion and also to minimize pitching.

93 The position of the car very near to the gas bag, is one of the features of the Government dirigible. This reduces the length and consequently the resistance of the suspension, and places the propeller thrust near the center of resistance.

94 The total lifting power of this airship is 1350 lb. of which 500 lb. are available for passengers, ballast, fuel, etc. At its official trials a speed of 19.61 miles per hour was attained over a measured course ,and an endurance run lasting 2 hours, during which 70 per cent of the maximum speed was maintained.

95 *Dirigible No.* 1. as this airship has been named, has already served a very important purpose in initiating offieers of the Signal Corps in the construction and operation of a dirigible balloon. With the experience now acquired, the United States Government is in a position to proceed with the construction and operation of an airship worthy of comparison with any now in existence, but any efforts in this direction must await the action of Congress in providing the necessary funds.

BALLOON PLANT AT FORT OMAHA, NEBRASKA

96 In anticipation of taking up the subject of aëronautics on a scale commensurate with its importance, a complete plant has been

constructed at the Signal Corps post at Fort Omaha, Nebraska. This plant comprises a steel balloon house 200 ft. long, 84 ft. wide, and 75 ft. high; that is, large enough to house a dirigible balloon of the size of the new French Military Airship *Le Republique.* For furnishing hydrogen gas, an electrolytic plant has been installed capable of furnishing 3000 cu. ft. of gas per hour. A gasometer of 50 000 cu. ft. capacity has been provided to store a sufficient supply of gas for emergencies.

97 In connection with the hydrogen plant, is a compressor for charging under pressure the steel tubes in which the gas is transported. A hydraulic pump for testing steel tubes at high pressure is a part of this equipment. A steel wireless telegraph tower 200 ft. high has been completed, and probably will be used in connection with wireless experiments with dirigible balloons.

Some General Considerations Which Govern the Design of a Dirigible Balloon

BUOYANCY AND SHAPE

98 Although many aërodynamic data are needed for the proper design of a dirigible airship, yet the experience already available in the construction and performance of such ships built on different plans is sufficient to enable the engineer to proceed with the design of a dirigible balloon to accomplish definite results along fairly accurate lines. In the case of this class of lighter-than-air ships the following general equation obtains:

$$W - w = V\left(\sigma - \frac{\sigma}{n}\right) \tag{1}$$

where

W = weight of balloon, envelope, car, and aëronauts
V = volume of balloon
σ = density of the air
n = density of air as compared with gas
w = weight of air displaced by car and aëronauts and envelope of balloon.

99 If we call the weight of the gas in the balloon M, then we can write this equation in the following manner:

$$W + M = w + nM$$

from which we find that

and

$$M = \frac{W - w}{n - 1} \tag{2}$$

$$V = \left(\frac{W - w}{\sigma}\right)\left(\frac{n}{n - 1}\right) \tag{3}$$

thus obtaining the volume of gas required. If the volume of the gas-bag, car, aëronauts, etc. $= v$, then $w = v\sigma$; so that (3) may be written

$$V = \left(\frac{W - v\sigma}{\sigma}\right)\left(\frac{n}{n - 1}\right) \tag{4}$$

100 Thus far, certainly, no dirigible balloon has ever been developed which, has attained an independent speed greater than 40 miles per hour. It will readily be admitted that an airship so designed as to reach a speed of 50 or 60 miles per hour would be regarded as a most decided step forward in the art, since this difference of velocity is just the increment needed to place such craft on a practical basis capable of maneuvering in the air in all ordinary weather. This advancement, although requiring much consideration, would fully compensate in practical results.

101 The first point to be decided upon in the design of an airship is the method of maintaining the shape of the gas-bag against the pressure encountered at the maximum velocity to be attained. There are two schools of design in this respect, each having its adherents. One maintains the shape of the gas-bag by a rigid interior frame, and the other by means of the internal pressure of the gas itself.

102 Upon the selection of the type depends to a large extent the particular shape of the envelope. If the envelope is to maintain its shape by interior pressure of gas, evidently it must be so designed that the maximum pressure of the air developed at the speed contemplated shall not be sufficient to cause deformation of any part of the envelope. This can be effected only by making the uniform internal pressure at least equal to the maximum external pressure. Since the maximum external pressure occurs over the prow of the air-ship, this evidently is the particular part which must receive most careful attention with this system.

103 The desirable shape of head would evidently be one where the distribution of external pressure due to air resistance at the

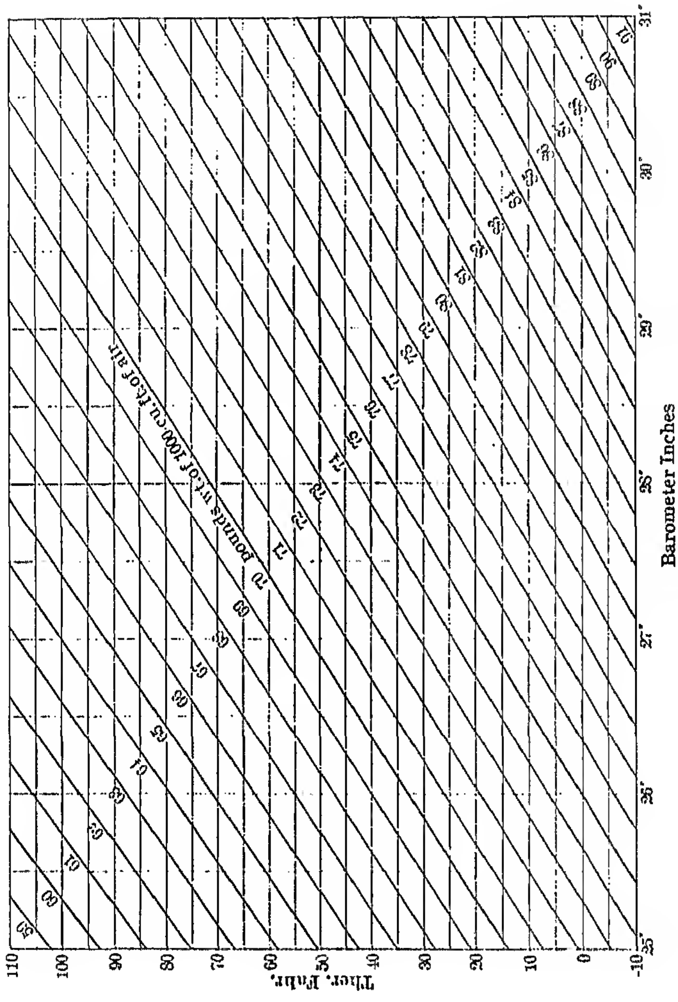

DIAGRAM FOR FINDING THE ASCENSIONAL FORCE OF GASES

velocity used is uniform. In addition to preventing deformation of the gas-bag, a prime requisite also is that the shape shall be such that the total resistance, comprising head resistance and skin-friction shall be a minimum for a given displacement and velocity.

104 This immediately forces the question of the law of resistance of the air. On this subject there are numerous aërodynamic data for low velocities, and also for very high velocities, but such data are incomplete for the range of velocities here considered.

105 In fact, the law of resistance of the air for surfaces of revolution as experimentally determined, is known to vary not with any constant power of the velocity, but by a range of exponents from the first to the cube, if not higher. For example, in the enormous velocities attained by modern artillery, where bodies weighing a ton or more, are hurled through the air at 2000 ft. per second, it is known that the physical phenomena become entirely different in nature from those found when dealing with moderate velocities such as are met in transportation devices.

RESISTANCE OF THE AIR TO THE MOTION OF A PROJECTILE

106 In the expression for the retardation of oblong projectiles the velocity enters with an exponent, n, whose accepted values are as follows:

		Ft. per second	Miles per hour
$n = 1.55$	for velocities greater than	2600 =	1773
$n = 1.7$	for velocities between....	2600 and 1800 =	1773 and 1227
$n = 2.$	for velocities between....	1800 and 1370 =	1227 and 934
$n = 3.$	for velocities between....	1370 and 1230 =	934 and 836
$n = 5.$	for velocities between....	1230 and 970 =	836 and 639
$n = 3.$	for velocities between....	970 and 790 =	639 and 592
$n = 2.$	for velocities less than ...	790 =	592

107 *14-in. and 16-in. Guns.* The 14-in. guns fire a projectile weighing 1660 lbs. Service muzzle velocity 2150 f. s., which gives with an elevation of 15 deg. a range of 15 000 yds.

108 The 16 in. guns fire a projectile weighing 2400 lbs. The Service muzzle velocity is 2150 f. s., or 1465 miles per hour, which gives, for an elevation of 15 deg. a range of 15 558 yd., or nearly 9 miles.

ANALOGY TO AIRSHIP

109 Great guns are now constructed which throw masses of steel weighing as high as 2400 lb. to maximum distances approximating

15 to 20 miles, and with such high momentum that ordinary winds have little effect, as shown by the remarkable target practice of the Army and Navy. The shapes of these heavier-than-air flying machines are figures of revolution, and the longitudinal and lateral stability are maintained by imparting to the projectile a rotary motion about its longer axis by means of the rifling inside the bore of the gun. Such machines are 5000 or 6000 times heavier than air and travel at speeds far beyond any other engine constructed by man. No peripheral speeds attained with any machinery approach these velocities.

110 It is noted that these projectile air-machines have a mass two and a half times that of the Wright Aëroplane, and attain a velocity through the air thirty-six times as great.

111 It thus appears that the resistance of the air to the motion of bodies through it is in reality a complicated function of the velocity, and the best that can be said is that this velocity varies as a constant power only within certain limited ranges. In the velocities considered for airships, it is approximate to regard the resistance as varying as the square.

112 As the velocity increases the form of the head becomes more and more important, and moderate velocities lead to a shape approximating torpedo form, which is well known. In very high speed projectiles the shape of the rear is not so important, since the velocity is so much greater than the velocity of sound in air, that a partial vacuum is formed behind the projectile which cannot well be obviated.

113 If the rigid system be employed where an internal frame prevents deformation of the envelope, the stresses due to external pressure are taken up by the framework itself, and the gas required for flotation is usually contained in several separate receptacles or ballonets similar to compartments employed in ships. In this system, therefore, we are concerned only in securing such a shape of the rigid frame as will fulfill the condition of minimum total resistance for a given displacement and velocity.

114 Once the shape of the bag is determined from the considerations already enumerated, the dimensions become immediately fixed when the tonnage is assumed, or conversely, if any linear dimension is assigned the tonnage is thereby determined.

115 In addition to the two general systems above considered, there are various types involving some of the principles of each, which are classed in general as semi-rigid systems. Such systems usually comprise a rigid frame, to which is attached the gas-bag above, and the load below.

AËRODYNAMIC ADJUSTMENTS

116 The next step is one of structural design along strictly engineering lines. The aërodynamic features of airship construction may be considered under the heads: (*a*) static balance; (*b*) dynamic balance; (*c*) stability; (*d*) natural period and oscillation.

117 *Static Balance.* The dimensions of the gas-bag being determined, the lift of each transverse segment thereof is immediately known, and the design of the frame may proceed by approximate trial and correction as in other structural work. The weight of each segment of the envelope itself is readily computed, which added to the corresponding segment of the frame gives the total weight of each segment, and this total subtracted from the lift of each segment gives the net lift for that complete segment. From the magnitude and position of these net forces the position of the resultant lift is known, and this determines the vertical line through the center of gravity. Such procedure evidently insures static balance of the machine as a whole, and an approximate distribution of the load.

118 *Dynamic Balance.* The dynamic balance must also be carefully considered; and here a difficulty has been experienced on account of the inability to place the resultant thrust coincident with the line of resistance of the ship as a whole. Heretofore, it has been customary to balance the thrust-resistance couple by means of suitable horizontal rudders or planes, so situated and at such angles, that the resultant moment of the system should be zero at uniform speeds of travel, though not necessarily zero for accelerated motion.

119 If, however, the line of thrust be made coincident with the line of resistance, the disturbing moment in question will be eliminated at uniform speeds. If, furthermore, the center of mass be located on the line of thrust and sufficiently forward to form a righting couple with the resistance when the wind suddenly veers, the evil effects of a disturbing moment will be obviated for variable as well as for constant speeds. The ship is then dynamically balanced.

120 This, of course, requires that the form of hull be such that a quartering wind shall exert a force passing to the rear of the center of mass. To illustrate, a good example of dynamic balance is found in a submarine torpedo, or a fish.

121 *Stability.* The foregoing adjustments still allow the center of mass to be placed below the center of buoyancy. This is a provision that is important in aëronautics as well as in marine architecture, indeed it is the only practical provision for keeping an even

keel and preventing heeling when the ship is at rest, or simply drifting with the wind. If the center of gravity be well below the center of buoyancy, the vessel is proportionately stable, but, of course, the stability is pendular, and may admit of considerable rolling and pitching due to shifting loads, sudden gusts of wind, etc., unless special devices be used to dampen or prevent these effects.

122 *Natural Period and Oscillations.* It may happen also that the equilibrium of the ship is disturbed by periodic forces whose periods are simply related to the natural period of the ship itself. In this case the oscillations will be cumulative and may become very large. Such effects are well known to marine engineers, and may be treated as in ordinary ship design.

II. AVIATION

123 This division comprises all those forms of heavier-than-air flying machines which depend for their support upon the dynamic reaction of the atmosphere. There are several subdivisions of this class dependent upon the particular principle of operation. Among these may be mentioned the aëroplane, orthopter, helicopter, etc. The only one of these that has been sufficiently developed at present to carry a man in practical flight is the aëroplane. There have been a large number of types of aëroplanes tested with more or less success and of these the following are selected for illustration.

REPRESENTATIVE AËROPLANES OF VARIOUS TYPES

THE WRIGHT BROTHERS' AËROPLANE

124 The general conditions under which the Wright machine was built for the Government were, that it should develop a speed of at least 36 miles per hour, and in its trial flights remain continuously in the air for at least 1 hour. It was designed to carry two persons having a combined weight of 350 lb. and also sufficient fuel for a flight of 125 miles. The trials at Fort Myer, Virginia, in September of 1908, indicated that the machine was able to fulfill the requirements of the government specifications.

125 The aëroplane has two superposed main surfaces 6 ft. apart with a spread of 40 ft. and a distance of 6½ ft. from front to rear. The area of this double supporting surface is about 500 sq. ft. The surfaces are so constructed that their extremities may be warped at the will of the operator.

126 A horizontal rudder of two superposed plane surfaces about

15 ft. long and 3 ft. wide is placed in front of the main surfaces. Behind the main planes is a vertical rudder formed of two surfaces trussed together about 5½ ft. long and 1 ft. wide. The auxiliary surfaces, and the mechanism controlling the warping of the main surfaees, are operated by three levers.

127 The motor, which was designed by the Wright brothers, has four eylinders and is water cooled. It develops about 25 h.p. at 1400 r.p.m. There are two wooden propellers 8½ ft. in diameter which are designed to run at about 400 r.p.m. The machine is supported on two runners, and weighs about 800 lb. A monorail is used in starting.

128 The Wright machine has attained an estimated maximum speed of about 40 miles per hour. On September 12, a few days before the accident which wrecked the machine, a record flight of 1 hour, 14 minutes, 20 seconds was made at Fort Myer, Virginia. Since that date Wilbur Wright, at Le Mans, France, has made better records; on one occasion remaining in the air for more than an hour and a half with a passenger.

129 A reference to the attached illustrations of this machine will show its details, its method of starting, and its appearance in flight.

THE HERRING AËROPLANE

130 The Signal Corps of the Army has eontracted with A. M. Herring, of New York, to furnish an aëroplane under the conditions enumerated in the specification already referred to and shown in the appendix to this paper. Mr. Herring made technieal delivery of his machine at the aëronautieal testing ground at Fort Myer, Virginia, on October 13.

131 In compliance with the request of Mr. Herring the details of this machine will not be made public at present, but the official tests required under the contract will be eonducted in public as has been the case with other aëronautical devices. Opportunity will be afforded any one to observe the machine in operation.

132 This machine embodies new features for automatic control and contains an engine of remarkable lightness per horse-power.

THE FARMAN AËROPLANE

133 The Farman flying maehine has two superposed aërosurfaces 4 ft. 11 in. apart with a spread of 42 ft. 9 in. and 6 ft. 7 in. from front to rear. The total sustaining surface is about 560 sq. ft.

134 A box tail 6 ft. 7 in. wide and 9 ft. 10 in. long in rear of the main surfaces is used to balance the machine. The vertical sides of the tail are pivoted along the front edges, and serve as a vertical rudder for steering in a horizontal plane. There are two parallel, vertical partitions near the middle of the main supporting surfaces, and one vertical partition in the middle of the box tail. A horizontal rudder in front of the machine is used to elevate or depress it in flight.

135 The motor is an eight cylinder Antoinette of 50 h.p. weighing 176 lb., and developing about 38 h.p. at 1050 r.p.m.

136 The propeller is a built-up steel frame covered with aluminum sheeting, 7½ ft. in diameter, with a pitch of 4 ft. 7 in. It is mounted directly on the motor shaft immediately in rear of the middle of the main surfaces.

137 The framework is of wood, covered with canvas. A chassis steel tubing carries two pneumatic-tired bicycle wheels. Two smaller wheels are placed under the tail. The total weight of the machine is 1166 lb. The main surfaces support a little over two pounds per square foot. The machine has shown a speed of about 28 miles per hour and no starting apparatus is used.

138 On January 13, 1908, Farman won the *Grand Prix* of the Aëro Club of France in a flight of 1 minute and 28 seconds, in which he covered more than a kilometer. It is reported that on October 30, 1908, a flight of 20 miles, from Mourmelon to Rheims, was made with this machine.

THE BLERIOT AËROPLANE.

139 Following Farman's first flight from town to town, M. Bleriot with his monoplane aëroplane made a flight from Toury to the neighborhood of Artenay and back, a total distance of about 28 kilometers. He landed twice during these flights and covered 14 kilometers of his journey in about 10 minutes, or attained a speed of 52 miles an hour.

THE JUNE BUG

140 The *June Bug* was designed by the Aërial Experiment Association, of which Alexander Graham Bell is President. It has two main superposed aërosurfaces with a spread of 42 ft. and 6 in., including wing tips, with a total supporting surface of 370 sq. ft.

141 The tail is of the box type. The vertical rudder above the rear edge of the tail is 30 in. square. The horizontal rudder in front of the main surfaces is 30 in. wide by 8 ft. long. There are four

triangular wing tips pivoted along their front edges for maintaining transverse equilibrium. The vertical rudder is operated by a steering wheel, and the movable tips by cords attached to the body of the aviator.

142 The motor is a 25 h.p., 8 cylinder, air cooled, Curtiss. The single wooden propeller immediately behind the main surfaces is 6 ft. 2 in. in diameter and mounted directly on the motor shaft. It has a pitch angle of about 17 deg. and is designed to run at about 1200 r.p.m.

143 The total weight of the machine, with aviator, is 650 lb. It has a load of about $1\frac{3}{4}$ lb. per sq. ft. of supporting surface. Two pneumatic-tired bicycle wheels are attached to the lower part of the frame.

144 With this machine, Mr. G. H. Curtiss, on July 4, 1908, won the Scientific American trophy by covering the distance of over a mile in 1 minute and $42\frac{2}{5}$ seconds at a speed of about 39 miles per hour.

Some General Considerations Which Govern the Design of an Aëroplane

145 The design of an aëroplane may be considered under the heads of support, resistance and propulsion, stability and control.

146 *Support.* In this class of flying machines, since the buoyancy is practically insignificant, support must be obtained from the dynamic reaction of the atmosphere itself. In its simplest form, an aëroplane may be considered as a single plane surface moving through the air. The law of pressure on such a surface has been determined and may be expressed as follows:

$$P = 2\,k\sigma\,AV^2 \sin\,\alpha \qquad (1)$$

in which P is the normal pressure upon the plane, k is a constant of figure, σ the density of the air, A is the area of the plane, V the relative velocity of translation of the plane through the air, and α the angle of flight.

147 This is the form taken by Duchemin's formula for small angles of flight such as are usually employed in practice. The equation shows that the upward pressure on the plane varies directly with the area of the plane, with the sine of the angle of flight, with the density of the air, and also with the square of the velocity of translation.

148 It is evident that the total upward pressure developed must be at least equal to the weight of the plane and its load, in order to support the system. If P is greater than the weight the machine will ascend, if less, it will descend.

149 The constant k depends only upon the shape and aspect of the plane, and should be determined by experiment. For example, with a plane 1 foot square $k\sigma = 0.00167$, as determined by Langley, when P is expressed in pounds per square foot, and V in feet per second.

Equation (1) may be written

$$A\,V^2 = \frac{P}{2\,k\sigma \sin \alpha}.$$

If P and α are kept constant then the equation has the form

$$A\,V^2 = \text{constant}. \tag{2}$$

PRINCIPLE OF REEFING IN AVIATION

150 An interpretation of (2) reveals interesting relations. The supporting area varies inversely as the square of the velocity. For example, in the Wright aëroplane, the supporting area at 40 miles per hour is 500 sq. ft., while if the speed is increased to 60 miles per hour this area need be only $\frac{500}{1.5^2} = 222$ sq. ft., or less than one-half of its present size. At 80 miles per hour the area would be reduced to 125 sq. ft., and at 100 miles per hour only 80 sq. ft. of supporting area is required. These relations are conveniently exhibited graphically.

151 It thus appears that if the angle of flight be kept constant in the Wright aëroplane, while the speed is increased to one hundred miles per hour, we may picture a machine which has a total supporting area of 80 sq. ft., or a double surface each measuring about $2\frac{1}{2}$ by 16 ft. or 4 by 10 ft. if preferred. Furthermore, the discarded mass of the 420 sq. ft. of the original supporting surface may be added to the weight of the motor and propellers in the design of a reduced aëroplane, since in this discussion the total mass is assumed constant at 1000 lb.

152 In the case of a bird's flight, its wing surface is "reefed" as its velocity is increased, which instinctive action serves to reduce its head resistance and skin-frictional area, and the consequent power required for a particular speed.

153 *Determination of k for Arched Surfaces.* Since arched surfaces are now commonly used in aëroplane construction, and as the above equation (1) applies to plane surfaces only, it is important to determine experimentally the value of the coefficient of figure k, for each type of arched surface employed, especially as k is shown in some cases to vary with the angle of flight α; i.e. the inclination of the chord of the surface to the line of translation.

154 Assuming α constant, however, we may compare the lift of any particular arched surface with a plane surface of the same projected plan and angle of flight.

155 To illustrate, in the case of the Wright aëroplane, let us assume

P = 1000 lb. = total weight = W.
A = 500 sq. ft.
V = 40 miles per hour = 60 ft. per second.
α = 7 deg. approximately.

Whence
$$k\sigma = \frac{P}{2\,A\,V^2 \sin\alpha} = \frac{1000}{2 \times 500 \times 60^2 \times \frac{1}{8}}$$
$$= 0.0022 \;(V = \text{ft. sec.})$$
$$= 0.005 \;\;(V = \text{mi. hr.})$$

156 Comparing this value of $k\,\sigma$ with Langley's value 0.004 for a plane surface V being in miles per hour, we see that the lift for the arched surface is 25 per cent greater than for a plane surface of the same projected plan. That is to say, this arched surface is dynamically equivalent to a plane surface of 25 per cent greater area than the projected plan. Such a plane surface may be defined as the "equivalent plane."

157 *Resistance and Propulsion.* The resistance of the air to the motion of an aëroplane is composed of two parts: (a), the resistance due to the framing and load; (b), the necessary resistance of the sustaining surfaces, that is, the drift, or horizontal component of pressure; and the unavoidable skin-friction. Disregarding the frame, and considering the aëroplane as a simple plane surface, we may express the resistance by the equation

$$R = W \tan\alpha + 2\,f\,A \tag{3}$$

in which R is the total resistance, W the gross weight sustained, α the angle of flight, f the friction per square unit of area of the plane,

A the area of the plane. The first term of the second member gives the drift, the second term the skin-friction. The power required to propel the aëroplane is

$$H = R\ V$$

in which H is the power, V the velocity.

158 Now W varies as the second power of the velocity, as shown by equation (1), and f varies as the power 1.85, as will be shown later. Hence we conclude that the total resistance R of the air to the aëroplane varies approximately as the square of its speed, and the propulsive power practically as the cube of speed.

159 *Most Advantageous Speed and Angle of Flight.* Again, regarding W and A as constant, we may, by equation (1), compute α for various values of V, and find f for those velocities from the skin-friction table to be given presently. Thus α, R, and H may be found for various velocities of flight, and their magnitudes compared. In this way the values in Table 1 were computed for a soaring plane 1 ft. square weighing 1 lb., assuming $k\ \sigma = 0.004$, which is approximately Langley's value when V is in miles per hour.

COMPUTED POWER REQUIRED TO TOW A PLANE ONE FOOT SQUARE, WEIGHING ONE POUND, HORIZONTALLY THROUGH THE AIR AT VARIOUS SPEEDS AND ANGLES OF FLIGHT

Velocity	Angle of Flight	COMPUTED RESISTANCE Drift	Friction	Total	Tow-line power	Lift per tow-line h.p.
Mi. hr.	*Deg.*	*Lb.*	*Lb.*	*Lb.*	*Ft. lb. sec.*	*Lb.*
30	8.25	0.145	0.0170	0.162	7.13	77.1
35	6.04	0.104	0.0226	0.1266	6.51	84.3
40	4.52	0.790	0.0280	0.1070	6.32	86.7
45	3.55	0.0621	0.0360	0.0981	6.30	86.1
50	2.88	0.0500	0.0430	0.0930	6.80	80.2
60	2.03	0.0354	0.0614	0.0962	8.50	64.7
70	1.47	0.0257	0.0814	0.1071	11.00	50.0
80	1.12	0.0195	0.1045	0.1240	14.56	35.8
90	0.88	0.0154	0.1300	0.1454	19.17	28.7
100	0.71	0.0124	0.1584	0.1708	25.00	22.0

160 Column two, giving values of α for various speeds is computed from equation (1). Thus at 30 miles per hour,

$$\sin\,\alpha = \frac{W}{2\,k\,\sigma\,AV^2} = \frac{1}{2 \times .004 \times 1 \times 30^2}$$

whence $\alpha\ = 8.25$ deg.

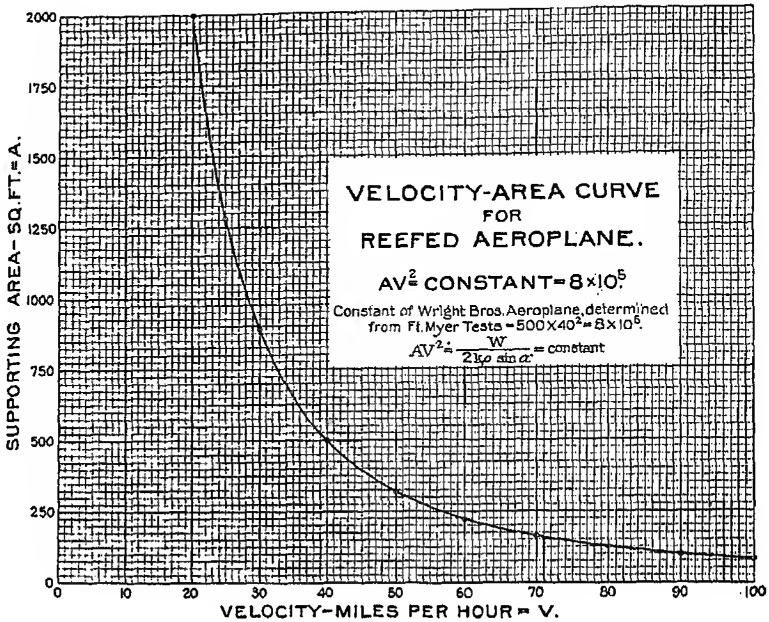

FIGURE A

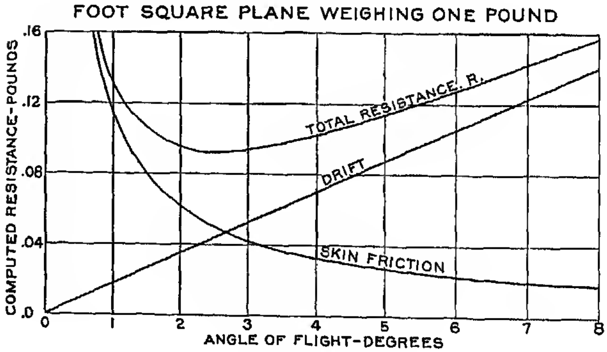

FIGURE B

161 Column three is computed from the term $W \tan \alpha$ in equation (3), thus

$$\text{Drift} = W \tan \alpha = 1 \times \tan 8.25 \text{ deg.} = 0.145.$$

162 Column four is computed from the term $2fA$, in equation (3), f being taken from the skin-friction table to be given presently.

163 The table shows that if a thin plane 1 ft. square, weighing 1 lb. be towed through the air so as just to float horizontally at various velocities and angles of flight, the total resistance becomes a minimum at an angle of slightly less than 3 deg., and at a velocity of about 50 miles per hour; also that the skin-friction approximately equals the drift at this angle. The table also shows that the propulsive power for the given plane is a minimum at a speed of between 40 and 45 miles per hour, the angle of flight then being approximately 4.5 deg.

164 The last column of the table shows that the maximum weight carried per horse-power is less than 90 lb. This horse-load may be increased by changing the foot square plane to a rectangular plane and towing it long-side foremost; also by lightening the load, and letting the plane glide at a lower speed; but best of all, perhaps, by arching it like a vulture's wing and also towing it long-side foremost as is the prevailing practice with aëroplanes.

These relations are exhibited graphically in the diagrams, Figs. B, C and D.

STABILITY AND CONTROL

165 The question of stability is a serious one in aviation, especially as increased wind velocities are encountered. In machines of the aëroplane type there must be some means provided to secure fore and aft stability and also lateral stability.

166 A large number of plans have been proposed for the accomplishment of these ends, some based upon the skill of the aviator, others operated automatically, and still others employing a combination of both. At the present time no aëroplane has yet been publicly exhibited which is provided with automatic control. There is little difference of opinion as to the desirability of some form of automatic control.

167 The Wright aëroplane does not attempt to accomplish this, but depends entirely upon the skill of the aviator to secure both lateral and longitudinal equilibrium, but it is understood that a

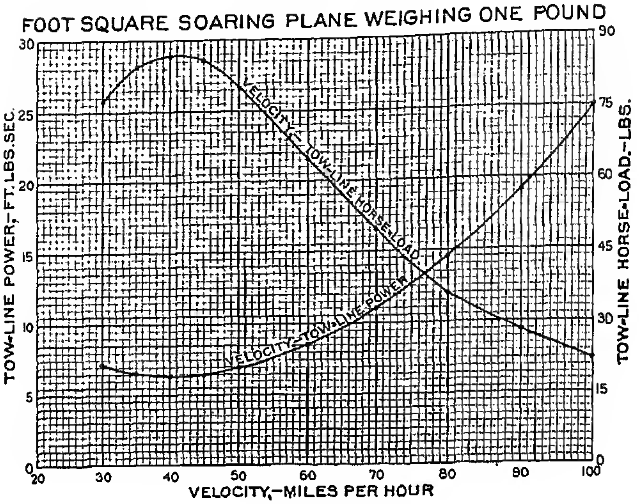

FIGURE C

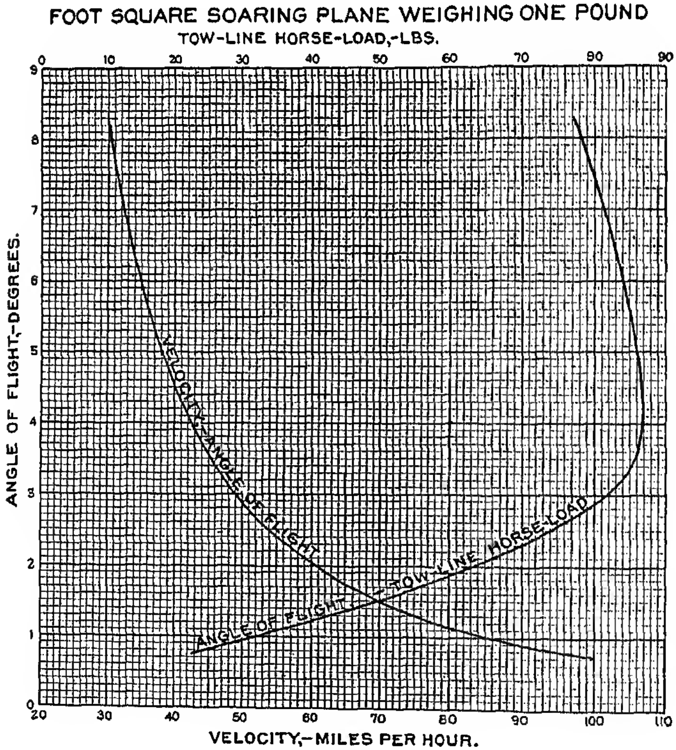

FIGURE D

device for this purpose is one of the next to be brought forward by them. Much of the success of the Wright brothers has been due to their logical procedure in the development of the aëroplane, taking the essentials, step by step, rather than attempting every thing at once, as is so often the practice with inexperienced inventors.

168 The aviator's task is much more difficult than that of the chauffeur. With the chauffeur, while it is true that it requires his constant attention to guide his machine, yet he is traveling on a roadway where he can have due warning through sight, of the turns and irregularities of the course.

169 The fundamental difference between operating the aëroplane and the automobile, is that the former is traveling along an aërial highway which has manifold humps and ridges, eddies and gusts, and since the air is invisible he cannot see these irregularities and inequalities of his path, and consequently cannot provide for them until he has actually encountered them. He must feel the road since he cannot see it.

170 Some form of automatic control whereby the machine itself promptly corrects for the inequalities of its path is evidently very desirable. As stated above, a large number of plans for doing this have been proposed, many of them based on gyrostatic action, movable side planes, revolving surfaces, warped surfaces, etc. A solution of this problem may be considered as one of the next important steps forward in the development of the aëroplane.

III. HYDROMECHANIC RELATIONS

Some General Relations Between Ships in Air and in Water

171 At the present moment, so many minds are engaged upon the general problem of aërial navigation that any method by which a broad forecast of the subject can be made is particularly desirable. Each branch of the subject has its advocates, each believing implicitly in the superiority of his method. On the one hand the adherents of the dirigible balloon have little confidence in the future of the aëroplane, while another class have no energy to devote to the dirigible balloon, and still others prefer to work on the pure helicopter principle. As a matter of fact, each of these types is probably of permanent importance, and each particularly adapted to certain needs.

172 Fortunately for the development of each type, the experiments made with one class are of value to the other classes, and these

in turn bear close analogy to the types of boats used in marine navigation. The dynamical properties of water and air are very much alike, and the equations of motion are similar for the two fluids, so that the data obtained from experiments in water, which are very extensive, may with slight modification be applied to computations for aërial navigation.

173 *Helmholz' Theorem.* Von Helmholz, the master physicist of Germany, who illuminated everything he touched, has fortunately considered this subject, in a paper written in 1873. The title of his paper is "On a theorem relative to movements that are geometrically similar in fluid bodies, together with an application to the problem of steering balloons."

174 In this paper Helmholz affirms that, although the differential equations of hydro-mechanics may be an exact expression of the laws controlling the motions of fluids, still it is only for relatively few and simple experimental cases that we can obtain integrals appropriate to the given conditions, particularly if the cases involve viscosity and surfaces of discontinuity.

175 Hence, in dealing practically with the motion of fluids, we must depend upon experiment almost entirely, often being able to predict very little from theory, and that usually with uncertainty. Without integrating, however, he applies the hydrodynamic equations to transfer the observations made on any one fluid with given models and speeds, over to a geometrically similar mass of another fluid involving other speeds, and models of different magnitudes. By this means he is able to compute the size, velocity, resistance, power, etc., of aërial craft from given, or observed, values for marine craft.

176 He also deduces laws that must inevitably place a limit upon the possible size and velocity of aërial craft without, however, indicating what that limit may be with artificial power. Applying this mode of reasoning to large birds he concludes by saying that, "It therefore appears probable that in the model of the great vulture, nature has already reached the limit that can be attained with the muscles as working organs, and under the most favorable conditions of subsistence, for the magnitude of a creature that shall raise itself by its wings and remain a long time in the air."

177 In comparing the behavior of models in water and air, he takes account of the density and viscosity of the media, as these were well known at the date of his writing, 1873; but he could not take account of the sliding, or skin-friction, because in his day neither

the magnitude of such friction for air, nor the law of its variation with velocity had been determined.

SKIN-FRICTION IN AIR

178 Even as late as Langley's experiments, skin-friction in air was regarded as a negligible quantity, but due to the work of Dr. Zahm who was the first to make any really extensive and reliable experiments on skin-friction in air, we now can estimate the magnitude of this quantity. As a result of his research he has given in his paper on atmospheric friction the following equation:

$$f = 0.00000778\ l^{-0.07}\ v^{1.85} \ldots (v = \text{ft. sec.}),$$
$$f = 0.0000158\ \ l^{-0.07}\ v^{1.85} \ldots (v = \text{mi. hr.})$$

in which f is the average skin-friction per square foot, and l the length of surface.

179 From this equation the accompanying table of resistances was computed, and is inserted here for the convenience of Engineers:

TABLE 2 FRICTION PER SQUARE FOOT FOR VARIOUS SPEEDS AND LENGTHS OF SURFACE

Wind speed	Average Friction in Pounds per Square Foot					
	1 ft. plane	2 ft. plane	4 ft. plane	8 ft. plane	16 ft. plane	32 ft. plane
mi. hr.						
5	0.000303	0.000280	0.000275	0.000262	0.000250	0.000238
10	0.00112	0.00105	0.00101	0.000967	0.000922	0.000878
15	0.00237	0.00226	0.00215	0.00205	0.00195	0.00180
20	0.00402	0.00384	0.00365	0.00349	0.00332	0.00317
25	0.00600	0.00570	0.00551	0.00527	0.00501	0.00478
30	0.00850	0.00810	0.00772	0.00736	0.00701	0.00668
35	0.01130	0.0108	0.0103	0.0098	0.00932	0.00888
40	0.0145	0.0138	0.0132	0.0125	0.0125	0.0114
50	0.0219	0.0209	0.0199	0.0190	0.0181	0.0172
60	0.0307	0.0293	0.0279	0.0265	0.0253	0.0242
70	0.0407	0.0390	0.0370	0.0353	0.0337	0.0321
80	0.0522	0.0500	0.0474	0.0452	0.0431	0.0411
90	0.0650	0.0621	0.0590	0.0563	0.0536	0.0511
100	0.0792	0.0755	0.0719	0.0685	0.0652	0.0622

180 The numbers within the rules represent data coming within the range of observation. These observations show that "the frictional resistance is at least as great for air as water, in proportion to their densities. In other words, it amounts to a decided obstacle

in high speed transportation. In aëronautics it is one of the chief elements of resistance both to hull-shaped bodies and to aëro-surfaces gliding at small angles of flight."

181 *Relative Dynamic and Buoyant Support.* Peter Cooper-Hewitt has given careful study to the relative behavior of ships in air and in water. He has made a special study of hydroplanes, and has prepared graphic representations of his results which furnish a valuable forecast of the problem of flight.

182 Without knowing of Helmholz's theorem, Cooper-Hewitt has independently computed curves for ships and hydroplanes from actual data in water, and has employed these curves to solve analogous problems in air, using the relative densities of the two media, approximately 800 to 1, in order to determine the relative values of support by dynamic reaction and by displacement for various weights and speeds.

183 An analysis of these curves leadsto conclusions of importance, some of which are as follows:

184 The power consumed in propelling a displacement vessel at any constant speed, supported by air or water, is considered as being $\frac{7}{8}$ consumed by skin-resistance, or surface resistance, and $\frac{1}{8}$ consumed by head resistance. Such a vessel will be about ten diameters in length, or should be of such shape that the sum of the power consumed in surface friction and in head resistance will be a minimum (torpedo shape).

185 The power required to overcome friction due to forward movement will be about $\frac{1}{8}$ as much for a vessel in air as for a vessel of the same weight in water.

186 Leaving other things out of consideration, higher speeds can be obtained in craft of small tonnage by the dynamic reaction type than by the displacement type, for large tonnages the advantages of the displacement of type are manifest.

187 A dirigible balloon carrying the same weight, other things being equal, may be made to travel about twice as fast as a boat for the same power; or be made to travel at the same speed with the expenditure of about $\frac{1}{8}$ of the power.

188 As there are practically always currents in the air reaching at times, a velocity of many miles per hour, a dirigible balloon should be constructed with sufficient power to be able to travel at a speed of about 50 miles per hour, in order that it may be available under practical conditions of weather. In other words, it should have substantially as much power as would drive a boat, carrying the same

weight, 25 miles an hour, or should have the same ratio of power to size as the "Lusitania."

189 *Motors.* It is the general opinion that any one of several types of internal combustion motors at present available is suitable for use with dirigible balloons. With this type, lightness need not be obtained at the sacrifice of efficiency. In the aëroplane, however, lightness per output is a prime consideration, and certainty and reliability of action is demanded, since if by chance the motor stops, the machine must immediately glide to the earth. A technical discussion of motors would of itself require an extended paper, and may well form the subject of a special communication.

190 *Propellers.* The fundamental principles of propellers are the same for air as for water. In both elements, the thrust is directly proportional to the mass of fluid set in motion per second. A great variety of types of propellers have been devised, but, thus far only the screw-propeller has proved to be of practical value in air. The theory of the screw-propeller in air is substantially the same as for the deeply submerged screw-propeller in water, and therefore does not seem to call for treatment here. There is much need at present for accurate aërodynamic data on the behavior of screw-propellers in air, and it is hoped that engineers will soon secure such data, and present it in practical form for the use of those interested in airship design.

191 *Limitations.* Euclid's familiar "square-cube" theorem connecting the volumes and surfaces of similar figures, as is well known, operates in favor of increased size of dirigibles, and limits the possible size of heavier-than-air machines in single units and with concentrated load.

192 It appears, however, that both fundamental forms of aërial craft will likely be developed, and that the lighter-than-air type will be the burden-bearing machine of the future, whereas the heavier-than-air type will be limited to comparatively low tonnage, operating at relatively high velocity. The helicopter type of machine may be considered as the limit of the aëroplane, when by constantly increasing the speed, the area of the supporting surfaces is continuously reduced until it practically disappears. We may then picture a racing aëroplane propelled by great power, supported largely by the pressure against its body, and with its wings reduced to mere fins which serve to guide and steady its motion. In other words, starting with the aëroplane type; we have the dirigible balloon on the one hand as the tonnage increases, and the helicopter type on the other extreme as the speed increases. Apparently, therefore, no one of

these forms will be exclusively used, but each will have its place for the particular work required.

IV. AËRIAL LOCOMOTION IN WARFARE

193 Whatever may be the influence of aërial navigation upon the Art of War, the fact which must be considered at present is, that each of the principal Military Powers is displaying feverish activity in developing this auxiliary as an adjunct to the military establishment.

194 If each of the great Powers of the world would agree that aërial warfare should not be carried on, the subject would be of no great interest to this country as far as our military policy is concerned, but until such an agreement is made this country is forced to an immediate and serious consideration of this subject in order to be prepared for any eventuality.

195 The identical reasoning which has led to the adoption of a policy of providing for increasing our Navy year by year to maintain our relative supremacy on the sea, is immediately applicable to the military control of the air. If the policy in respect to the Navy is admitted, there is no escape from the deduction that we should proceed in the development of ships of the air on a scale commensurate with the position of the Nation.

196 The question as to whether or not the Powers will ultimately permit the use of aërial ships in war is not at present the practical one, because in case such use is authorized it will be too late adequately to equip ourselves after war has been declared.

ACTION OF THE HAGUE PEACE CONFERENCE

197 The following is the declaration signed by the delegates of the United States to the Second International Peace Conference held at The Hague, June 15 to October 19, 1907, prohibiting the discharge of projectiles and explosives from balloons, ratified March 10, 1908.

198 Declaration:

The Contracting Powers agree to prohibit, for a period extending to the close of the Third Peace Conference, the discharge of projectiles and explosives from balloons or by other new methods of a similar nature.

199 The delegates of the United States signed this declaration. The countries which did not sign the declaration forbidding the launching of projectiles and explosives from balloons were: Germany,

Austria-Hungary, China, Denmark, Ecuador, Spain, France, Great Britain, Guatemala, Italy, Japan, Mexico, Montenegro, Nicaragua, Paraguay, Roumania, Russia, Servia, Sweden, Switzerland, Turkey, Venezuela.

200 It appears that the United States is the only first-class Power who signed this agreement, and an analysis of the text of the agreement itself shows that no serious attempt was made to settle the question finally.

201 For instance, while the war balloon may not discharge projectiles or explosives from above, yet no reciprocal provision is made preventing such war balloon from being fired upon from the earth below, yet the law of self-defense evidently obtains.

202 Furthermore, Naval Experts will tell you that they fear no enemy quite as much as a submarine mine, whose location is unknown and which gives no warning when it is approached. Our own experience shows that the Battleship Maine could be completely destroyed in time of peace without any one detecting the preparations for its accomplishment.

203 If, then, a nation can submerge a mine for the destruction of ships from underneath the water, why can it not drop an aërial mine upon a ship from above? And if it should be allowed to drop an aërial mine upon an enemy's fortified ship at sea, it certainly should be allowed to drop such an aërial mine upon a fortified place on land.

INFLUENCE ON THE MILITARY ART

204 The Military Art up to the present time, has been practically conducted in a plane where the armies concerned have been limited in their movements in time and place by the physical character of the terrane. A large army, for instance cannot move faster than about 12 miles a day by marching, and the use of railroads as applied to the Art of War was first recognized in the Franco-Prussian war. By their use, the mobilization of the great Prussian army, and its accurate assembling in the theater of operations within ten days, contributed an initial advantage not before possible.

205 The very essence of strategy is surprise, and there never were better opportunities than at present for a constructive General to achieve great victories. But these victories to be really great, must be founded upon some new development or use of power not heretofore known in war. They must also tend to produce results with the minimum loss of human life. In other words, the sentiment of

the world demands that the Military Art shall always aim to capture, not destroy.

206 It may be said, that the consummation of Military Art is found in maneuvering the enemy into untenable situations, thereby forcing a decisive result with a minimum loss of life and treasure.

207 As to the technical use of dirigible balloons and aëroplanes in warfare we have nothing but theory at present to guide us. It would appear, however, in the case of dirigible balloons that two different classes of such ships should be developed.

208 First: A comparatively small dirigible type with a capacity of from 50 000 to 100 000 cubic feet, to be used principally for scouting purposes and to a limited extent for carrying explosives for demolitions or for incendiary purposes, such as destroying bridges and supply depots close to the mobile army or coast defense fortress. In reconnoitering dirigibles of this class, in order to be safe during day-time they will have to maneuver at an altitude of about a mile, but experiments show that telephotographic apparatus will operate from this height to give much detail.

209 At night, such dirigibles may descend to within a few hundred feet of the ground with safety and thus obtain much valuable information. Equipped with wireless telegraph or telephone apparatus, military data could be obtained and transmitted without undue risk. Due to the small carrying capacity of such sizes, the radius of action would probably be limited at present to about two hundred miles.

210 Second: This type of dirigible may be developed for burden-bearing purposes. It has been pointed out above that the larger the airship the greater the speed it may be given, and the greater its radius of action. There is no reason to doubt, that airships of capacity, from 500 000 to 1 000 000 cubic feet may be ultimately developed to attain speeds of 50 to 75 miles per hour. With a capacity for such speed, the aërial craft becomes a powerful practical engine of war which may be used in all ordinary weather. By keeping high in the air in day-time, and descending at night, they may launch high explosives, producing great damage. Being able to pass over armies and proceed at great speeds, their objectives would not usually be the enemy's armies, but their efforts would be directed against his base of supplies; to destroy his dry-docks, arsenals, ammunition depots, principal railway centers, storehouses, and indeed the enemy's Navy itself.

211 It is thought that there will be little difficulty in launching explosives with accuracy, provided good maps and plans are available. Due to the small cost of such ships as compared with naval vessels, the risk of loss would be readily taken.

212 The element of time has always been a controlling factor in warfare. It is often a military necessity to conduct a reconnoissance in force to develop the enemy's dispositions. This requires at times a detachment of several thousand men from the main army, for a considerable period of time to accomplish this end. With efficient military airships, these results may be attained with a very few men in a small fraction of the time heretofore required.

213 *Delimitation of Frontiers.* The realization of aërial navigation for military purposes, brings forward new questions regarding the limitation of frontiers. As long as military operations are confined to the surface of the earth, it has been the custom to protect the geographical limits of a country by ample preparations in time of peace, such as a line of fortresses properly garrisoned. At the outbreak of war these boundaries represent real and definite limits to military operations. Excursions into the enemy's territory usually require the backing of a strong military force. Under the new conditions, however, these geographic boundaries no longer offer the same definite limits to military movements. With a third dimension added to the theater of operations, it will be possible to pass over this boundary on rapid raids for obtaining information, accomplishing demolitions, etc., returning to safe harbors in a minimum time. We may, therefore, regard the advent of military ships of the air, as, in a measure, obliterating present national frontiers in conducting military operations.

214 One of the military objectives in warfare, is usually the enemy's capital city, his ministers, and his chief Executive. This objective has heretofore been protected by large armies of soldiers, who, in themselves are not so important to the result. In order to attain the objective, it has been frequently necessary to subdue large numbers of soldiers needlessly.

215 With the advent of efficient ships of the air, however, small parties may pass over these protective armies on expeditions aimed at the seat of government itself, where reside the body of particular individuals most responsible, so that the ultimate result will be to deter a rash entrance into war for personal ends; since now for the first time responsible individuals of state may be in immediate and personal danger after the declaration of war, which heretofore has not been usually the case.

INTERIOR HARBORS

216 In the development of these larger types of dirigible balloons the main difficulty will be, in providing suitable harbors or places of safety, for replenishing supplies and for seeking shelter in times of stress. As long as the dirigible balloon remains in the air it may be regarded as tolerably safe, both in itself, and as a conveyance for observers. If its engines are disabled, it is at least a free balloon and may be operated as such.

217 When brought in contact with the ground, however, it is in considerable danger from high winds. The momentum of such an enormous airship is great, and the comparatively fragile structure of the craft makes it an easy prey to the pounding which it is likely to receive when landing. Just as marine ships must seek a sheltered harbor or put to the open sea in times of storm, so in case of ships of the air, it is much more necessary either to brave the storm in the open, or to seek some sheltered harbor on land.

218 Fortunately, in this case, certain suitable harbors for very large ships may be provided at small expense, by using narrow and deep valleys and ravines, surrounded by forests or other protection, or prepared railway cuts, etc., where the airship may descend and be reasonably safe from the winds above. These harbors should, of course, be known to the pilot, and carefully plotted on his maps beforehand. The compass bearings of each harbor from prominent points on land must be known and plotted, to assist as far as possible in navigating the airship in thick weather; and such harbors may be indicated to the pilot at night by vertical searchlight beams, or by suitable rockets, etc.

219 The aëroplane, as has been pointed out, is likely to prove a flying machine of comparatively low tonnage and high speed. It is not likely to become a burden-bearing ship, at least in single units, but will be extremely useful for reconnoitering purposes; for dispatching important orders and instructions at high speed; for reaching inaccessible points; or for carrying individuals of high rank and command to points where their personality is needed.

220 One of the bloodiest contests the world has ever seen, was the Japanese attack on "203 Meter Hill," yet, the sole object of this great slaughter, was for the purpose of placing two or three men at its summit to direct the fire of the Japanese siege guns upon the Russian fleet in the harbor at Port Arthur.

221 If the United States had possessed in 1898, a single dirigible

balloon, even of the size of the one now at Fort Myer, Virginia, which cost less than $10 000, the American Army and Navy would not have long remained in doubt of the presence of Cervera's fleet in Santiago Harbor.

222 The world is undoubtedly growing more humane year by year. We have arrived at a conception of the principle of an efficient Army and Navy, not to provoke war but to preserve peace, and it is believed, that, following this principle, the perfection of ships of the air for military purposes will materially contribute, on the whole, to make war less likely in the future than in the past.

APPENDIX NO. 1

SIGNAL CORPS SPECIFICATION, NO. 486

Advertisement and Specification for a Heavier-than-Air Flying Machine.

To the Public:

Sealed proposals, in duplicate, will be received at this office until 12 o'clock noon on February 1, 1908, on behalf of the Board of Ordnance and Fortification for furnishing the Signal Corps with a heavier-than-air flying machine. All proposals received will be turned over to the Board of Ordnance and Fortification at its first meeting after February 1 for its official action.

Persons wishing to submit proposals under this specification can obtain the necessary forms and envelopes by application to the Chief Signal Officer, United States Army, War Department, Washington, D. C. The United States reserves the right to reject any and all proposals.

Unless the bidders are also the manufacturers of the flying machine they must state the name and place of the maker.

Preliminary.—This specification covers the construction of a flying machine supported entirely by the dynamic reaction of the atmosphere and having no gas bag.

Acceptance.—The flying machine will be accepted only after a successful trial flight, during which it will comply with all requirements of this specification. No payments on account will be made until after the trial flight and acceptance.

Inspection.—The Government reserves the right to inspect any and all processes of manufacture.

GENERAL REQUIREMENTS.

The general dimensions of the flying machine will be determined by the manufacturer, subject to the following conditions:

1. Bidders must submit with their proposals the following:
   - (*a*) Drawings to scale showing the general dimensions and shape of the flying machine which they propose to build under this specification.
   - (*b*) Statement of the speed for which it is designed.
   - (*c*) Statement of the total surface area of the supporting planes.
   - (*d*) Statement of the total weight.
   - (*e*) Description of the engine which will be used for motive power.
   - (*f*) The material of which the frame, planes, and propellers will be constructed. Plans received will not be shown to other bidders.

2. It is desirable that the flying machine should be designed so that it may be quickly and easily assembled and taken apart and packed for transportation in army wagons. It should be capable of being assembled and put in operating condition in about one hour.

3. The flying machine must be designed to carry two persons having a combined weight of about 350 pounds, also sufficient fuel for a flight of 125 miles.

4. The flying machine should be designed to have a speed of at least forty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight, according to the following scale:

40 miles per hour, 100 per cent.
39 miles per hour, 90 per cent.
38 miles per hour, 80 per cent.
37 miles per hour, 70 per cent.
36 miles per hour, 60 per cent.
Less than 36 miles per hour rejected.
41 miles per hour, 110 per cent.
42 miles per hour, 120 per cent.
43 miles per hour, 130 per cent.
44 miles per hour, 140 per cent.

5. The speed accomplished during the trial flight will be determined by taking an average of the time over a measured course of more than five miles, against and with the wind. The time will be taken by a flying start, passing the starting point at full speed at both ends of the course. This test subject to such additional details as the Chief Signal Officer of the Army may prescribe at the time.

6. Before acceptance a trial endurance flight will be required of at least one hour during which time the flying machine must remain continuously in the air without landing. It shall return to the starting point and land without any damage that would prevent it immediately starting upon another flight. During this trial flight of one hour it must be steered in all directions without difficulty and at all times under perfect control and equilibrium.

7. Three trials will be allowed for speed as provided for in paragraphs 4 and 5. Three trials for endurance as provided for in paragraph 6, and both tests must be completed within a period of thirty days from the date of delivery. The expense of the tests to be borne by the manufacturer. The place of delivery to the Government and trial flights will be at Fort Myer, Virginia.

8. It should be so designed as to ascend in any country which may be encountered in field service. The starting device must be simple and transportable. It should also land in a field without requiring a specially prepared spot and without damaging its structure.

9. It should be provided with some device to permit of a safe descent in case of an accident to the propelling machinery.

10. It should be sufficiently simple in its construction and operation to permit an intelligent man to become proficient in its use within a reasonable length of time.

11. Bidders must furnish evidence that the Government of the United States has the lawful right to use all patented devices or appurtenances which may be a part of the flying machine, and that the manufacturers of the flying machine are authorized to convey the same to the Government. This refers to the unrestricted right to use the flying machine sold to the Government, but does not contemplate the exclusive purchase of patent rights for duplicating the flying machine.

12. Bidders will be required to furnish with their proposal a certified check amounting to ten per cent of the price stated for the 40-mile speed. Upon making the award for this flying machine these certified checks will be returned to the bidders, and the successful bidder will be required to furnish a bond, according to Army Regulations, of the amount equal to the price stated for the 40-mile speed.

13. The price quoted in proposals must be understood to include the instruction of two men in the handling and operation of this flying machine. No extra charge for this service will be allowed.

14. Bidders must state the time which will be required for delivery after receipt of order.

JAMES ALLEN
Brigadier General, Chief Signal Officer of the Army

SIGNAL OFFICE,
Washington, D. C., December 23, 1907

APPENDIX NO. 2

SIGNAL CORPS SPECIFICATION, NO. 483.

ADVERTISEMENT AND SPECIFICATION FOR A DIRIGIBLE BALLOON.

Bidders are requested to read carefully every paragraph of this specification and include in their proposal every detail called for.

To the public.—Sealed proposals, in duplicate, will be received at this office until 12 o'clock noon on February 15, 1908, and no proposals will be considered which are received after that hour.

Persons wishing to submit proposals under this specification can obtain the necessary forms and envelopes by application to the Chief Signal Officer, United States Army, War Department, Washington, D.C. The United States reserves the right to reject any and all proposals.

Unless the bidders are also the manufacturers of the dirigible balloon they must state the name and place of the maker.

Preliminary.—This specification covers the construction of a dirigible balloon, to consist of a gas bag supporting a suitable framework on which will be mounted the necessary propelling machinery.

Inspection.—The Chief Signal Officer of the Army will reserve the right to inspect any and all processes of manufacture, and unsatisfactory material will be marked for rejection by the inspectors before assembling.

Acceptance.—The dirigible balloon will be accepted only after a trial flight, during which it will comply with all requirements of this specification.

GENERAL REQUIREMENTS.

The general dimensions of the dirigible balloon will be determined by the manufacturer, subject to the following conditions:

1. The gas bag shall be designed for inflation with hydrogen. The material for the gas bag shall be furnished by the bidder, and shall be subject to approval by the Chief Signal Officer of the Army, and must have a minimum breaking strength of not less than 62½ pounds per inch width and must require no varnish. The dimensions and shape of the gas bag will be as desired by the manufacturer, except that the length must not exceed one hundred and twenty (120) feet.

2. Inside the gas bag there will be either one or two ballonets having a total capacity of at least one-sixth the total volume of the gas bag. Leading to the ballonets there will be tubes of proper size connected to a suitable centrifugal blower for maintaining a constant air pressure in the ballonets. The approved fabric for the ballonets must have a minimum tensile strength of not less than 48½ pounds per inch width.

3. *Valves.*—In the lower part of the ballonet and gas bag, or on the ballonet air tubes near the gas bag, there will be an adjustable automatic valve designed

to release air from the ballonet to the outside atmosphere. On the under side of the gas bag there will be a second adjustable automatic valve of suitable size, so designed as to release hydrogen from the interior of the gas bag to the outside atmosphere. This valve will also be arranged so that it may be opened at will by the pilot.

4. In the upper portion of the gas bag there will be provided a ripping strip covering an opening five (5) inches wide by six (6) feet long, with a red rip cord attached in the usual manner and brought down within reach of the pilot through a suitable gas-tight rubber plug inserted in a wooden ring socket.

5. The suspension system and frame must be designed to have a factor of safety of at least three, taking into account wind strains as well as the weight suspended.

6. A type of frame which can be quickly and easily assembled and taken apart will be considered an advantage.

7. The balloon must be designed to carry two persons having a combined weight of 350 pounds; also at least 100 pounds of ballast, which may be used to compensate for increased weight of balloon when operating in rain.

8. The dirigible balloon should be designed to have a speed of twenty miles per hour in still air, but bidders must submit quotations in their proposals for cost depending upon the speed attained during the trial flight acording to the following schedule:

20 miles per hour, 100 per cent.
19 miles per hour, 85 per cent.
18 miles per hour, 70 per cent.
17 miles per hour, 55 per cent.
16 miles per hour, 40 per cent.
Less than 16 miles per hour rejected.
21 miles per hour, 115 per cent.
22 miles per hour, 130 per cent.
23 miles per hour, 145 per cent.
24 miles per hour, 160 per cent.

9. The speed accomplished during the trial flight will be determined by taking an average of the time over a measured course of between two and five miles against and with the wind. The time will be taken by a flying start, passing the starting point at full speed at both ends of the course. This test subject to such additional details as the Chief Signal Officer of the Army may prescribe at the time.

10. Provision must be made to carry sufficient fuel for continuous operation of the engine for at least two hours. This will be determined by a trial endurance flight of two hours, during which time the airship will travel continuously at an average speed of at least 70 per cent of that which the airship accomplishes during the trial flight for speed stated in paragraph 9 of this specification. The engine must have suitable cooling arrangements, so that excessive heating will not occur.

11. Three trials will be allowed for speed as provided for in paragraph 9, and three trials for endurance as provided for in paragraph 10, and both tests must be completed within a period of thirty days from the date of delivery, the expense of the tests to be borne by the manufacturer. The place of delivery to the Government and trial flights will be at Fort Myer, Virginia.

12. The scheme for ascending and descending and maintaining equilibrium must be regulated by shifting weights, movable planes, using two ballonets or other approved method. Balancing by the aëronaut changing his position will not be accepted.

13. This dirigible balloon will be provided with a rudder of suitable size, a manometer for indicating the pressure within the gas bag, and all other fittings and appurtenances which will be required for successful and continuous flights, according to this specification.

14. Bidders will be required to furnish with their proposal a certified check amounting to fifteen per cent of the price stated for the 20-mile speed. Upon making the award for this airship these certified checks will be returned to bidders, and the successful bidder will be required to furnish a bond, according to Army Regulations, of the amount equal to the price stated for 20-mile speed.

15. Bidders must submit with their proposals drawings to scale showing the general dimensions and shape of the dirigible balloon which they propose to build under this specification; the horsepower and description of the engine which will be used for the motive power; the size, pitch and number of revolutions of the propellers; drawing illustrating the suspension system for attaching frame to gas bag; horse power and description of blower for forcing air into ballonets; volume of gas bag; volume of ballonets; the material of which the frame will be constructed; size of valves, etc. Plans received will not be shown to other bidders.

16. Bidders must furnish evidence that the Government of the United States has the lawful right to use all patented devices or appurtenances which may be part of the dirigible balloon and that the manufacturers of the dirigible balloon are authorized to convey the same to the Government. This refers to the right of the Government to use this dirigible balloon without liability for infringement of other inventors' patents. It does not contemplate the exclusive purchase of patent rights for duplicating the airship.

17. The prices quoted in proposals must be understood to include the instruction of two men in the handling and operation of this airship. No extra charge for this service will be allowed.

JAMES ALLEN
Brigadier General, Chief Signal Officer of the Army

Signal Office
Washington, D. C., January 21, 1908

APPENDIX NO. 3

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Bollettino della Societa Aeronautica, Rome
Vozdookhoplavatel, St. Petersburg

AËRONAUTICAL SOCIETIES OF THE WORLD

INTERNATIONAL SCIENTIFIC SOCIETIES

The International Commission for Scientific Aëronautics, Paris
The Permanent International Aëronautical Committee, Paris
Federation Aeronautique Internationale, Paris

NATIONAL SOCIETIES (Germany)

Deutscher Luftschiffer-Verband, Augsburg
Berliner Verein fur Luftschiffahrt, Berlin
Münchener Verein fur Luftschiffahrt, Munich
Oberrheinischer Verein fur Luftschiffahrt, Strassbourg
Augsburger Verein fur Luftschiffahrt, Augsburg
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Posener Verein fur Luftschiffahrt, Posen
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Frankischer Verein fur Luftschiffahrt, Wurzburg
Mittelrheinischer Verein fur Luftschiffahrt, Coblenz
Kolner Klub fur Luftschiffahrt, Kallenburg
Physikalischer Verein im Frankfort, Frankfort
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SOCIETIES OF OTHER NATIONS

Wiener Flugtechnischer Verein, Vienna
Wiener Aëro Club, Vienna
Aëro Club Suisse, Berne
Aëronautical Society of Great Britain, London
Aëro Club of the United Kingdom, London

Aëro Club of America, New York
Aëro Club of New England, Boston
Aëro Club of Philadelphia, Philadelphia
The Philadelphia Aëronautical Recreation Society,Philadelphia
Aëro Club of Ohio, Canton, Ohio
Aëro Club of St. Louis, St. Louis
Milwaukee Aëro Club, Milwaukee
Ben Franklin Aëronautical Society, Philadelphia
North Adams Aëro Club, North Adams, Mass.
Pittsfield Aëro Club, Pittsfield, Mass.
The Aëronautical Society, New York
Aëro Club of Chicago, Chicago
Aëronautique Club of Chicago, Chicago
Aëro Club of San Antonio, San Antonio, Texas
Svenska Aëronautiska Sallskapet, Stockholm
Société Francais de Navigation Aerienne, Paris
Aëronautique Club de France, Paris and Lyons
Aëro Club de France, Paris
Academie Aëronautique de France, Paris
Société des Aëronautes du Siege, Paris
Aëro Club du Sud-Ouest, Bordeaux
Aëro Club du Rhone, Lyon
Aëro Club du Nord, Roubaix
Club Aeronautique de l'Aube, Troye
Automobile Club de Nice, Nice
Aëro Club de Belgique, Brussels
Societa Aeronautica Italiana, Rome
Aviation Club de France, Paris
Russian Aëronautical Society, St. Petersburg
El Real Aëro-Club de Espana, Madrid

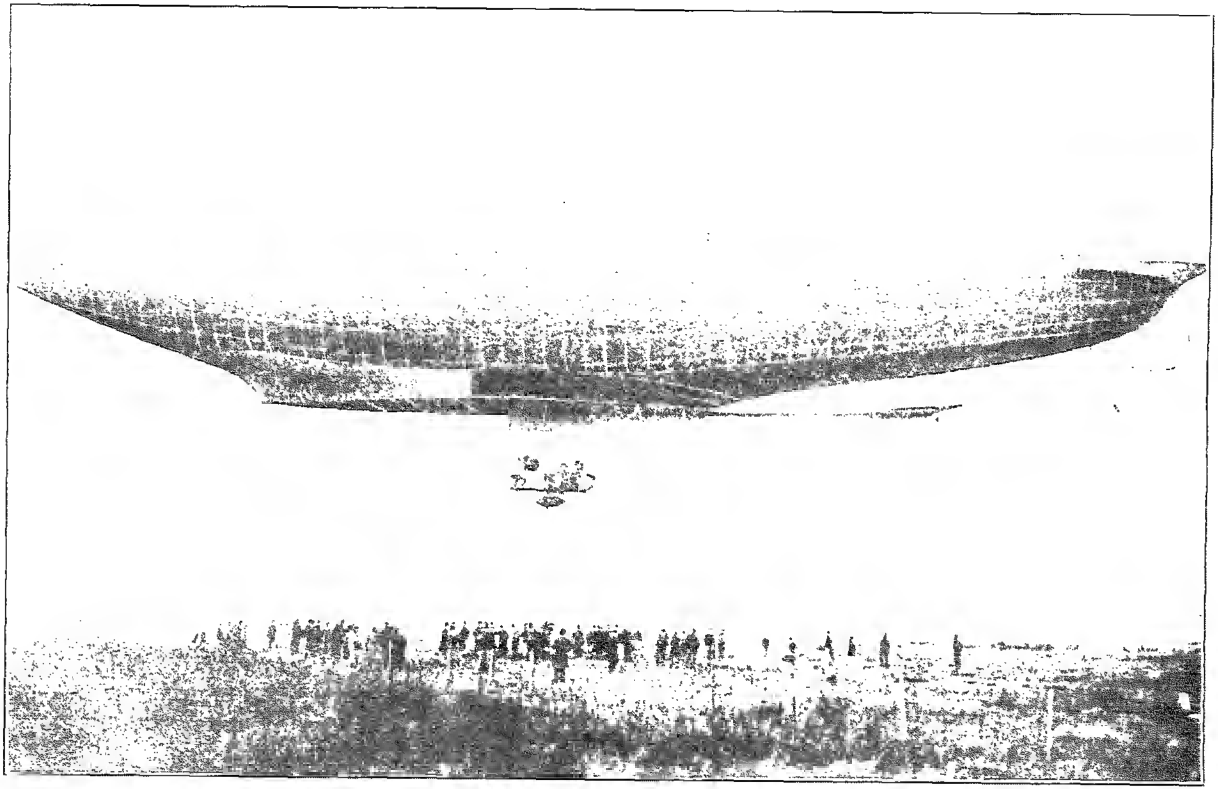


Fig. 1. French Dirigible "Patrie."

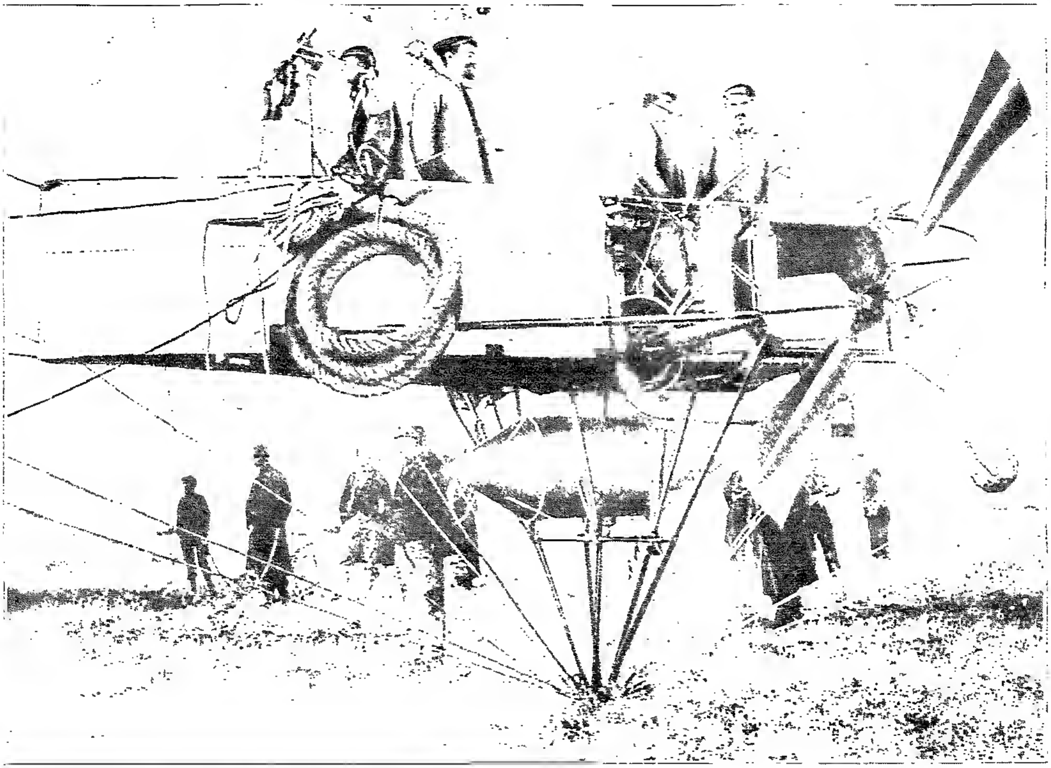


Fig. 2 French Dirigible "Patrie" Details of Car

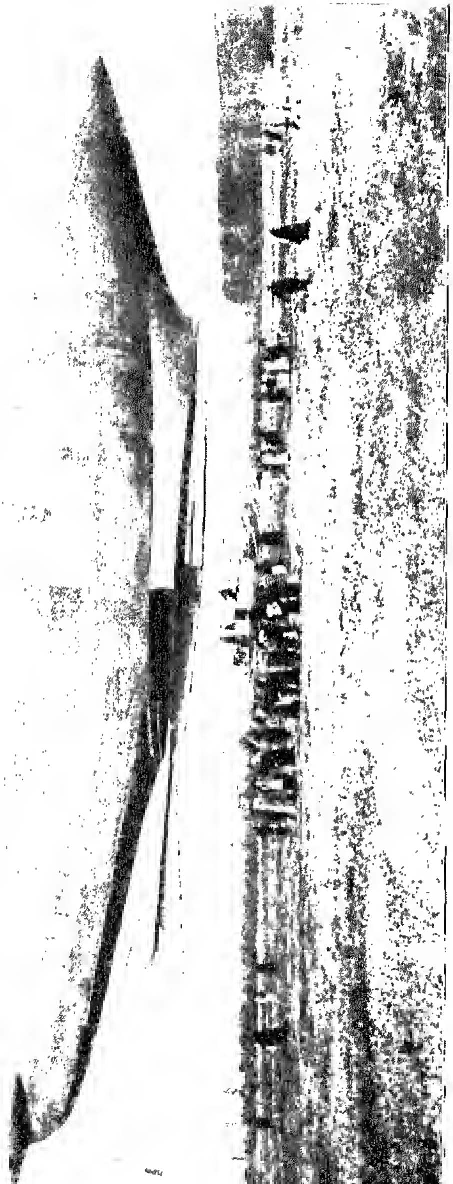


Fig. 5. French Dirigible "La Ville de Paris"

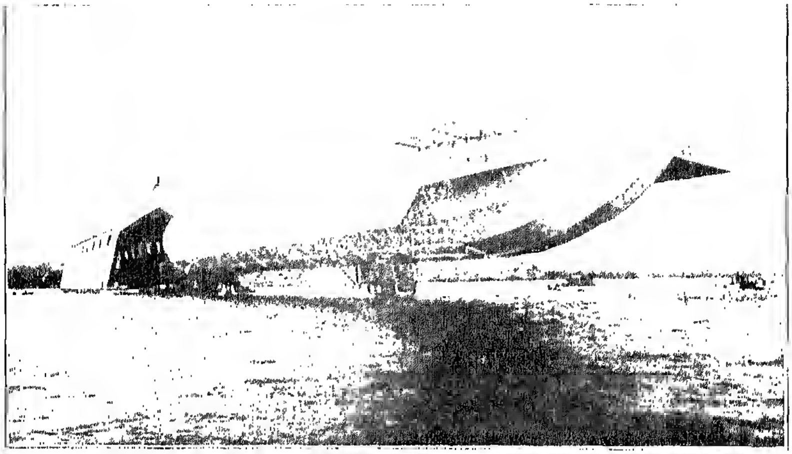


Fig. 6. German Dirigible "Zeppelin," with Floating Hangar

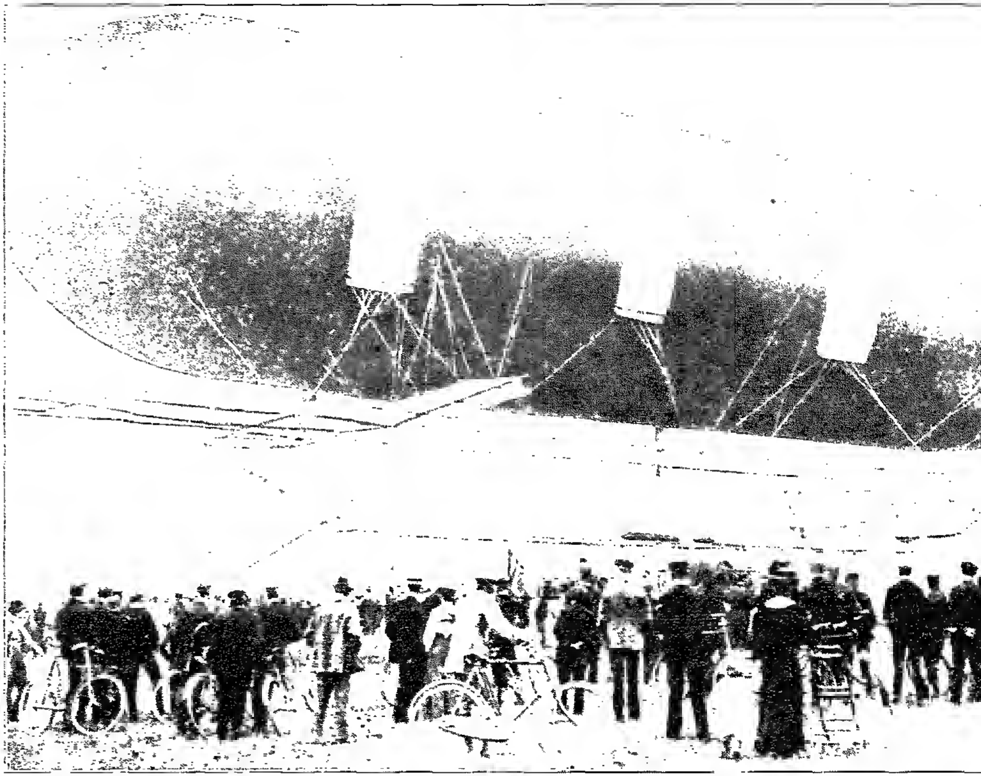


Fig. 5 English Dirigible No. 1

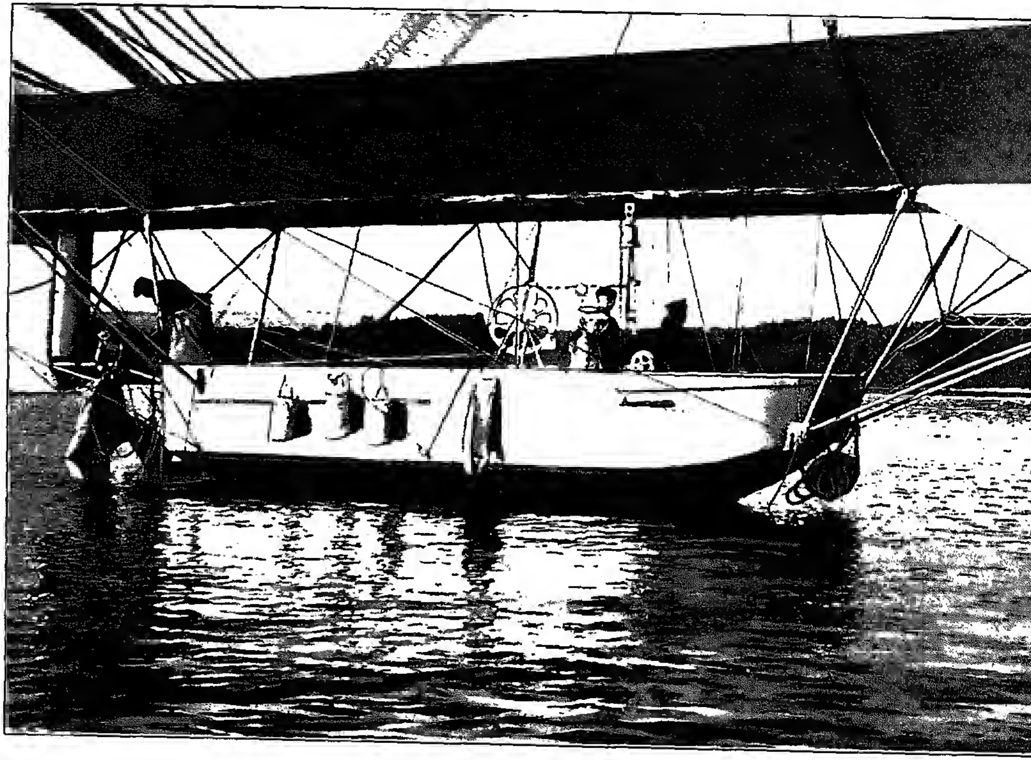


Fig. 7 German Dirigible "Zeppelin;" Details of Car

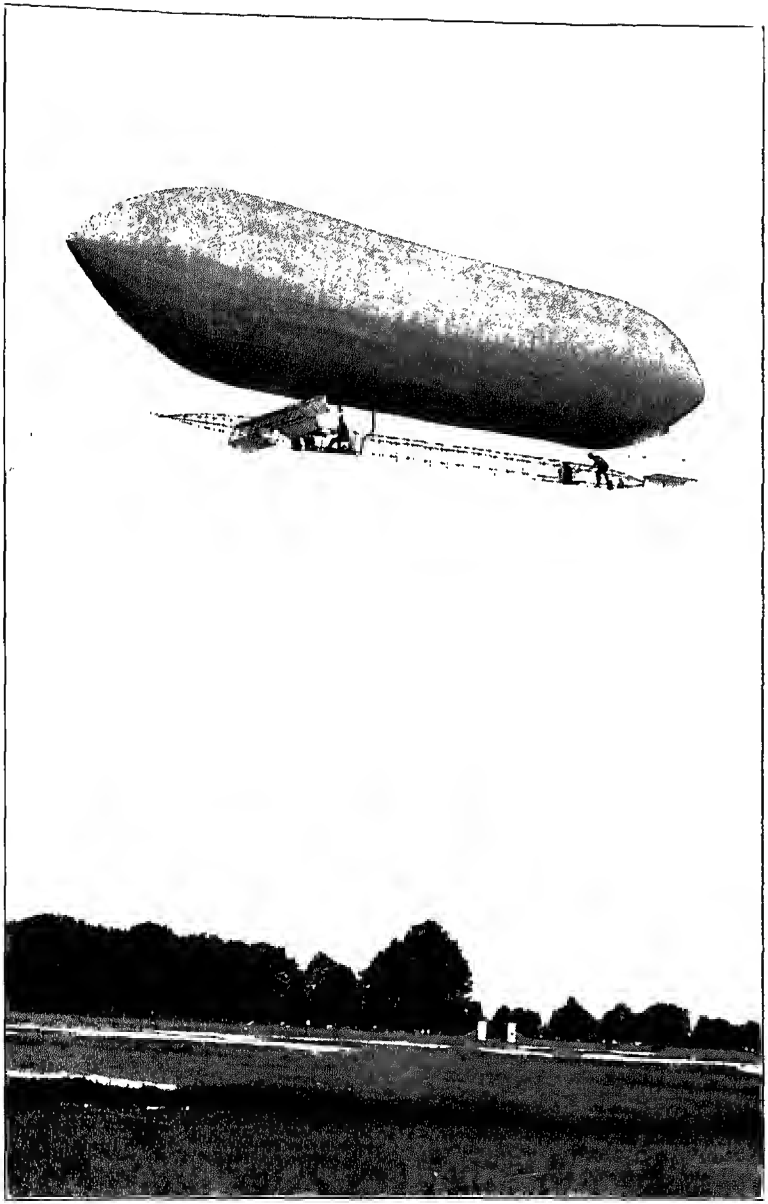


Fig. 8 Signal Corps Dirigible No. 1, in Flight, Fort Myer, Va., August, 1908

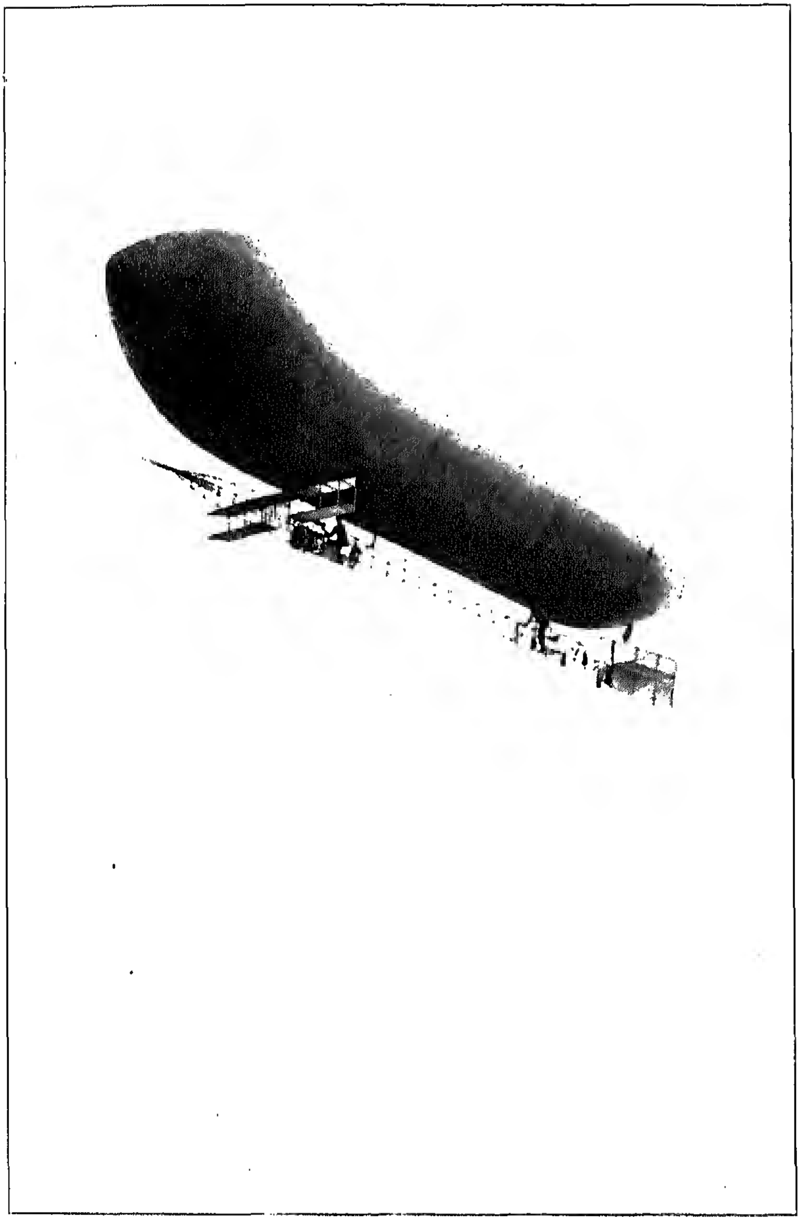


FIG. 9 SIGNAL CORPS DIRIGIBLE NO. 1, IN FLIGHT. FORT MYER VA., AUGUST, 1908

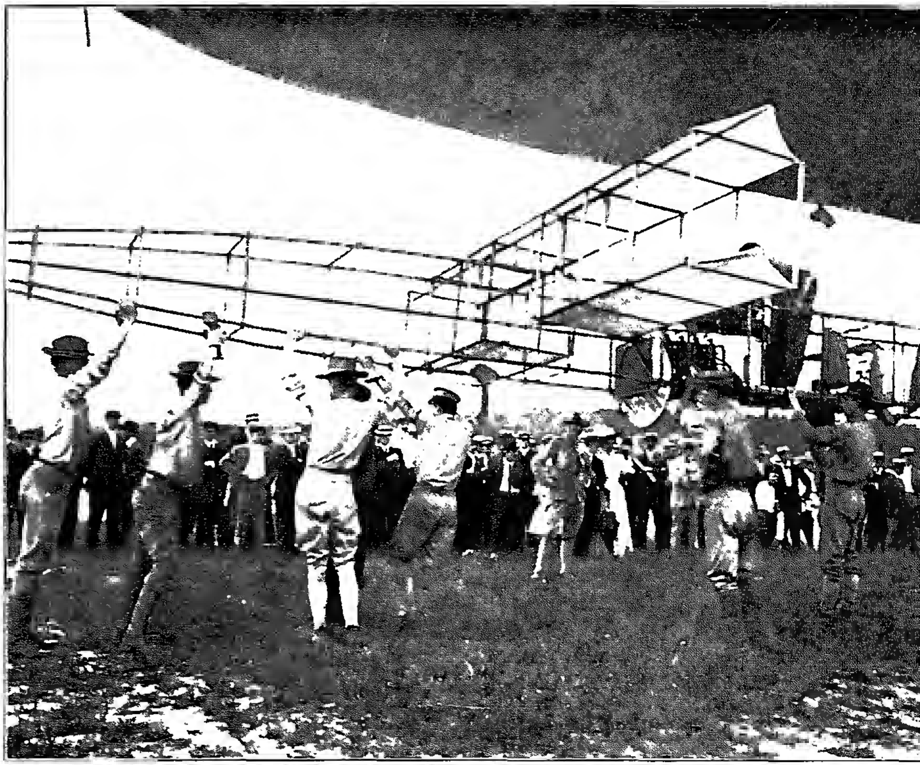


Fig. 10 Signal Corps Dirigible No 1, Showing Details of Front Manœuver

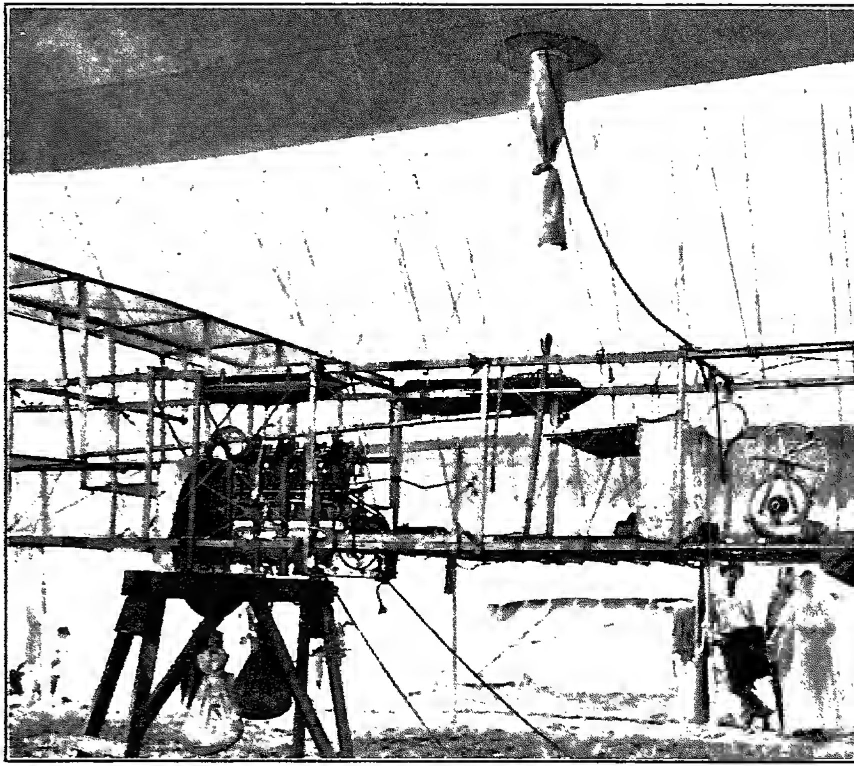


Fig. 11 Signal Corps Dirigible No. 1, Showing Details of C

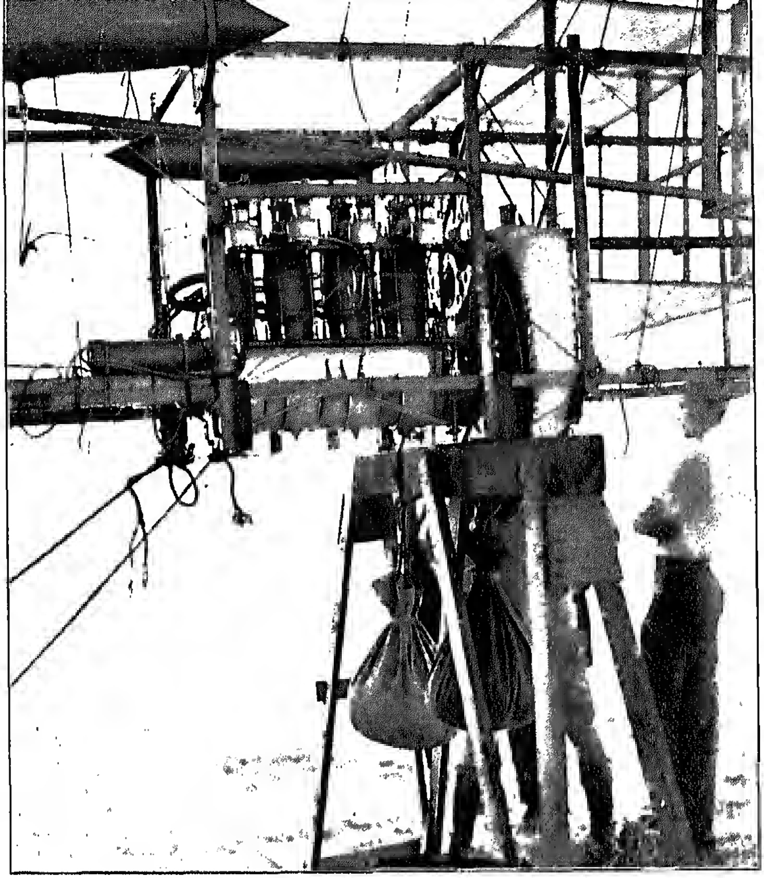


FIG. 12 SIGNAL CORPS DIRIGIBLE NO. 1, SHOWING DETAILS OF ENGINE

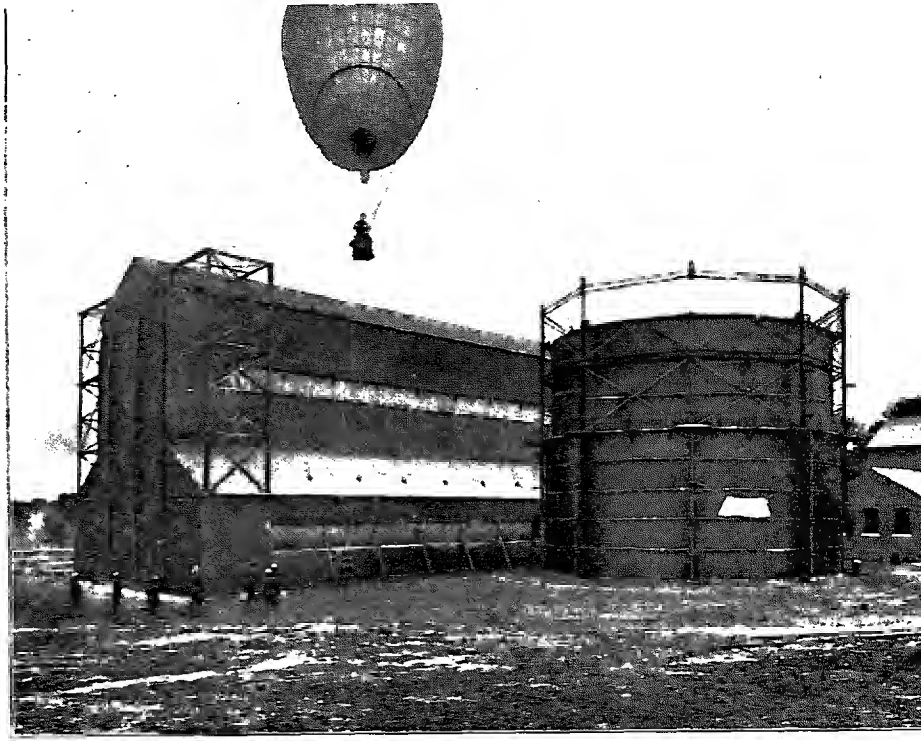


Fig. 13 Steel Balloon House, Gasometer and Hydrogen Generating Plant, Signal Co
Nebraska

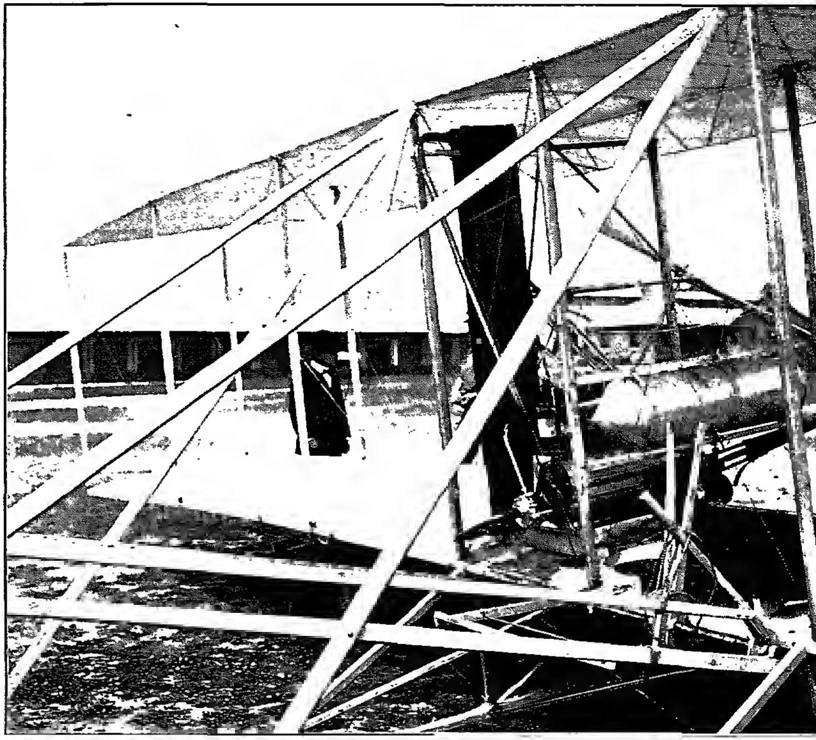


FIG. 14 WRIGHT BROTHERS' AËROPLANE; DETAILS OF CONSTRUC

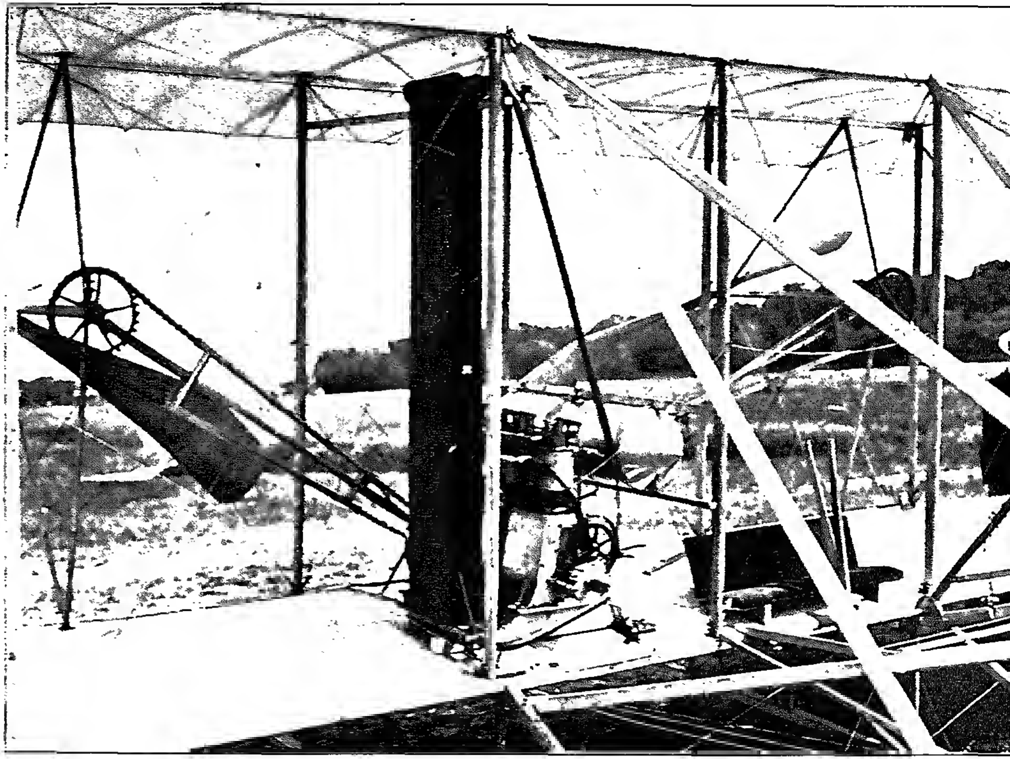


FIG. 15 WRIGHT BROTHERS' AËROPLANE: DETAILS OF CONSTRUCTION

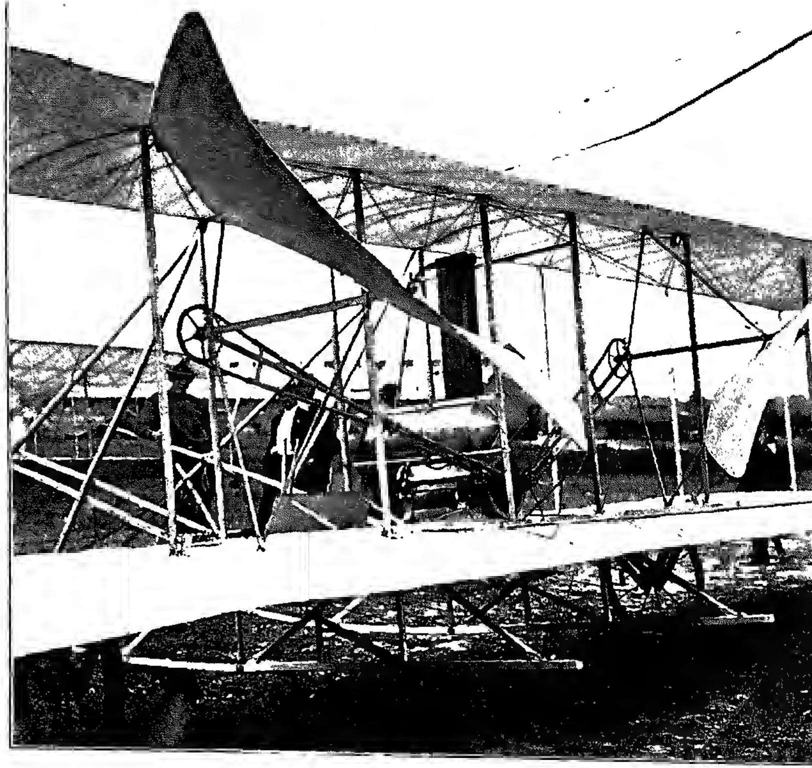


Fig. 16 Wright Brothers' Aëroplane; Details of Construction, Ri

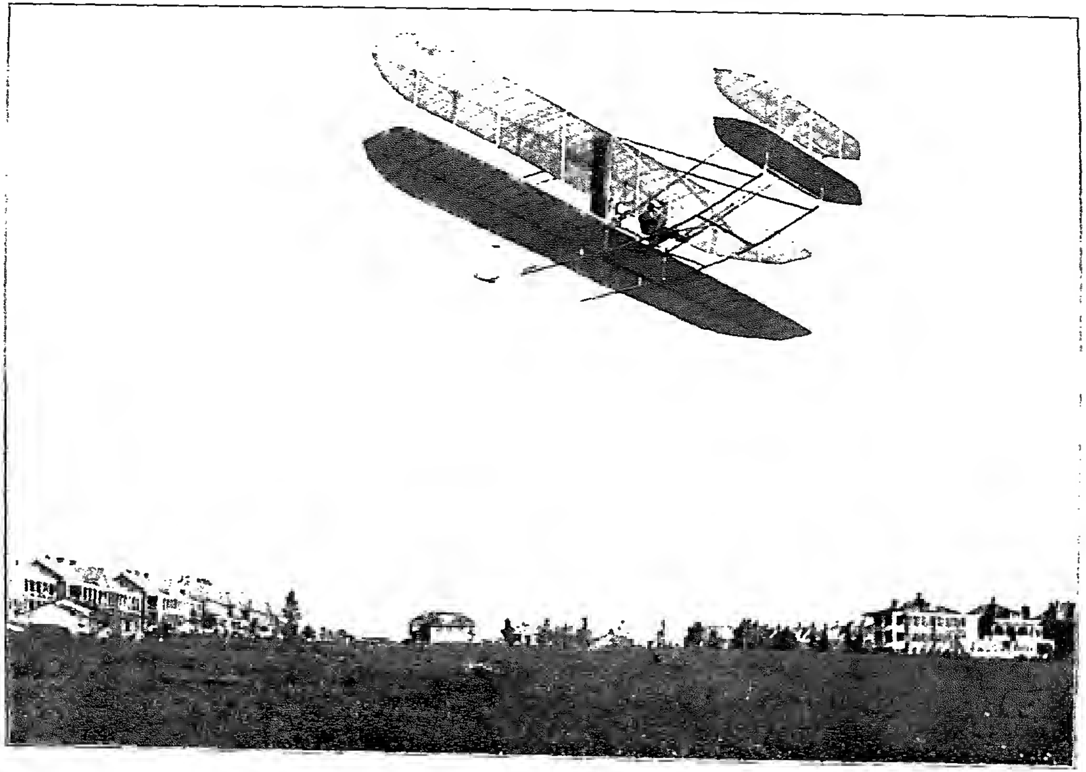


Fig. 17 Wright Brothers' Aëroplane, Fort Myer, Va., September 9, 1908

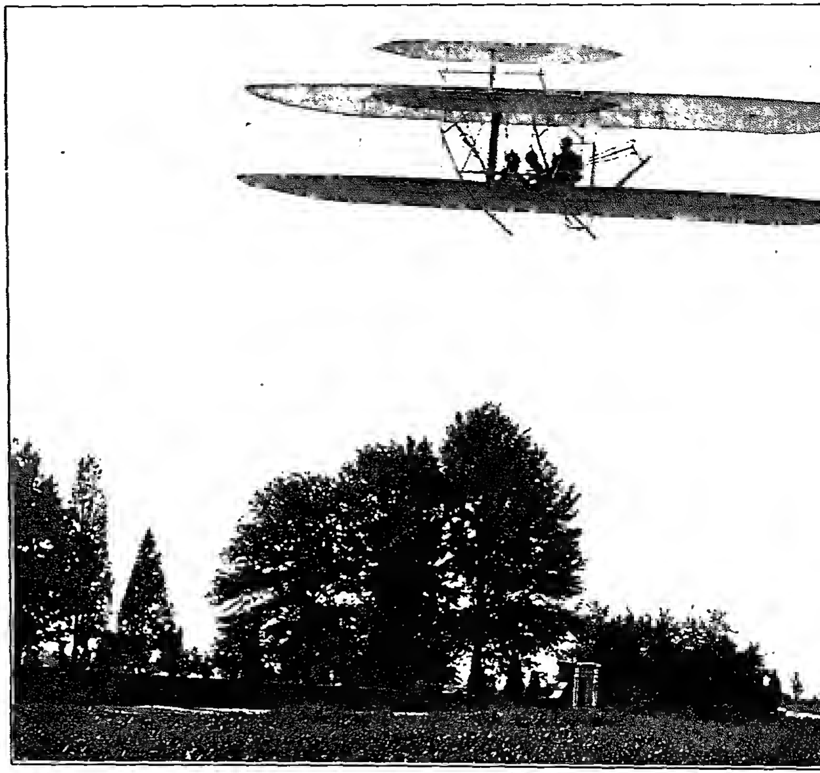


FIG. 18 WRIGHT BROTHERS' AËROPLANE, FORT MYER, VA., SEPTEMBER

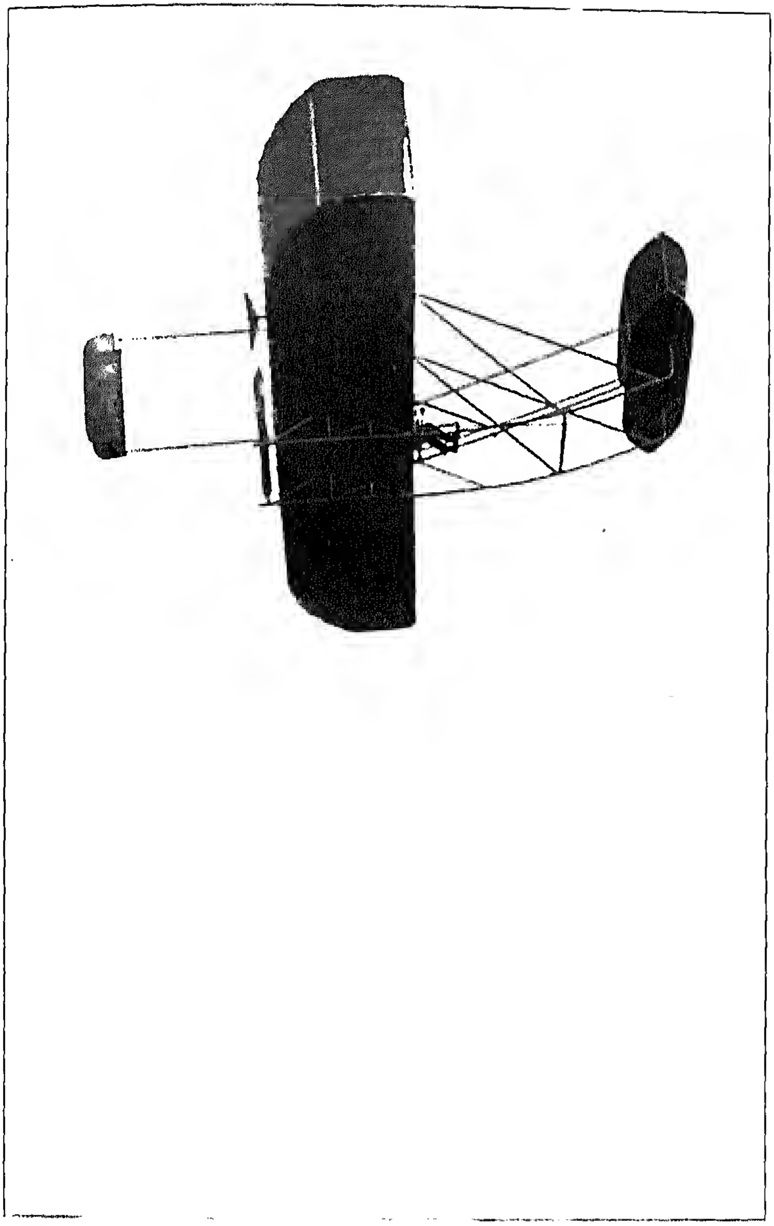


FIG. 19 WRIGHT BROTHERS' AEROPLANE, FORT MYER, VA., SEPTEMBER 12, 1908

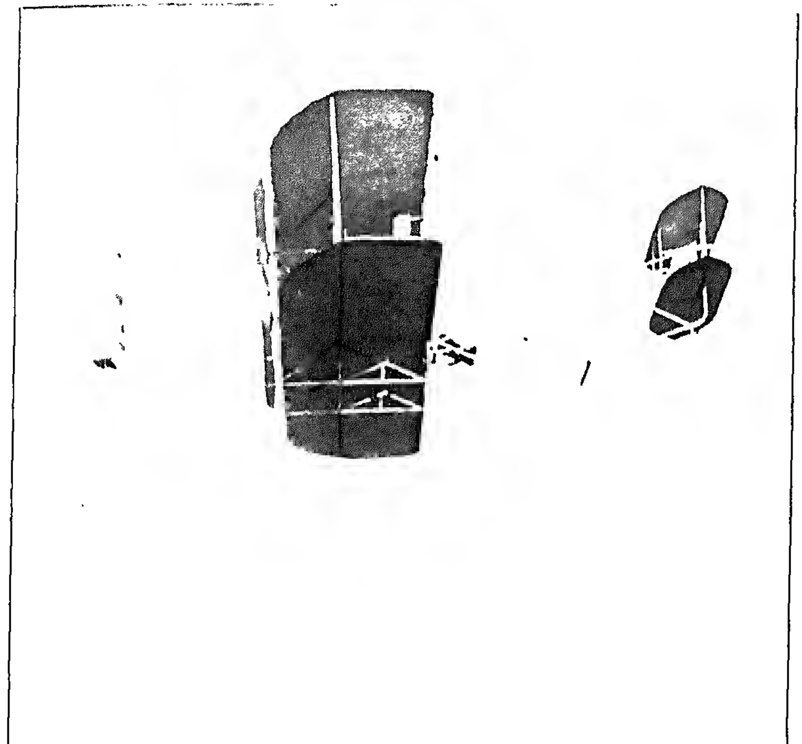


FIG. 20 WRIGHT BROTHERS' AEROPLANE, FORT MYER, VA., SEPTEMBER 12, 1908. TIME OF FLIGHT, 1 HR., 14 MIN., 20 SEC.

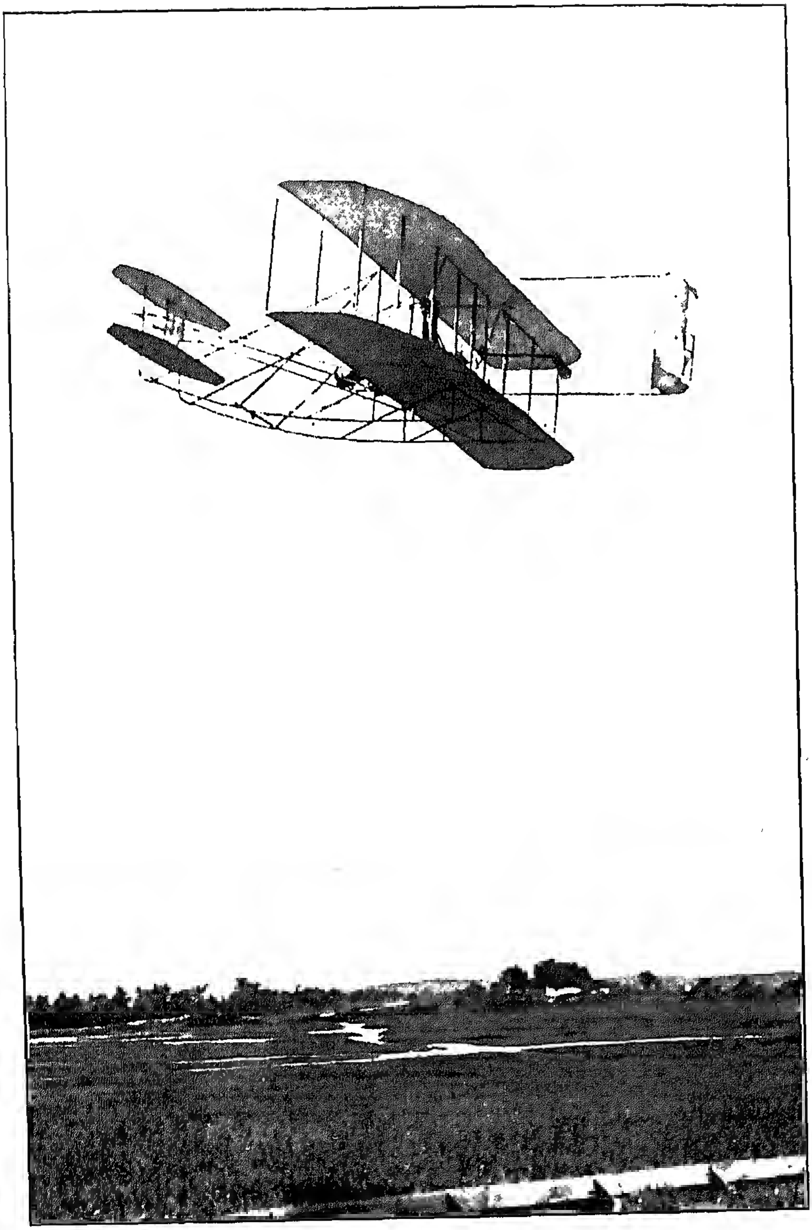


Fig. 21 Wright Brothers' Aëroplane, Fort Myer, Va., September 12, 1908. Time of Flight, 1 Hr., 14 Min., 20 sec.

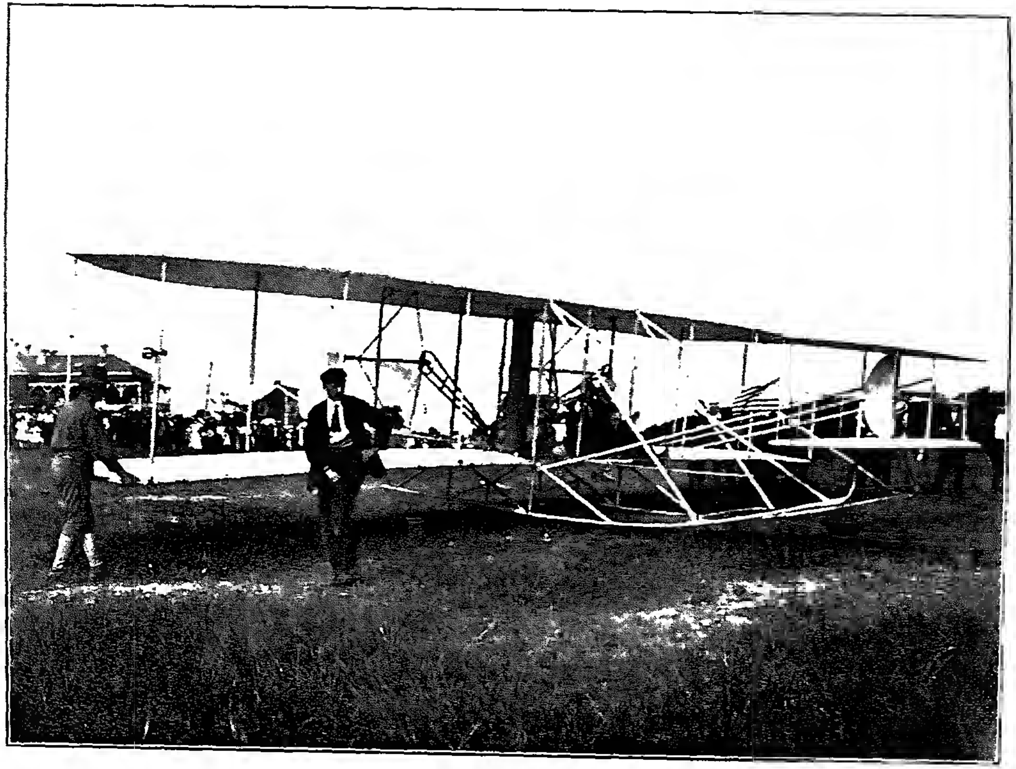


Fig. 22 Wright Brothers' Aëroplane, Fort Myer, Va., September 12, 1908; Ready for the Start; Orville Wright and Passenger

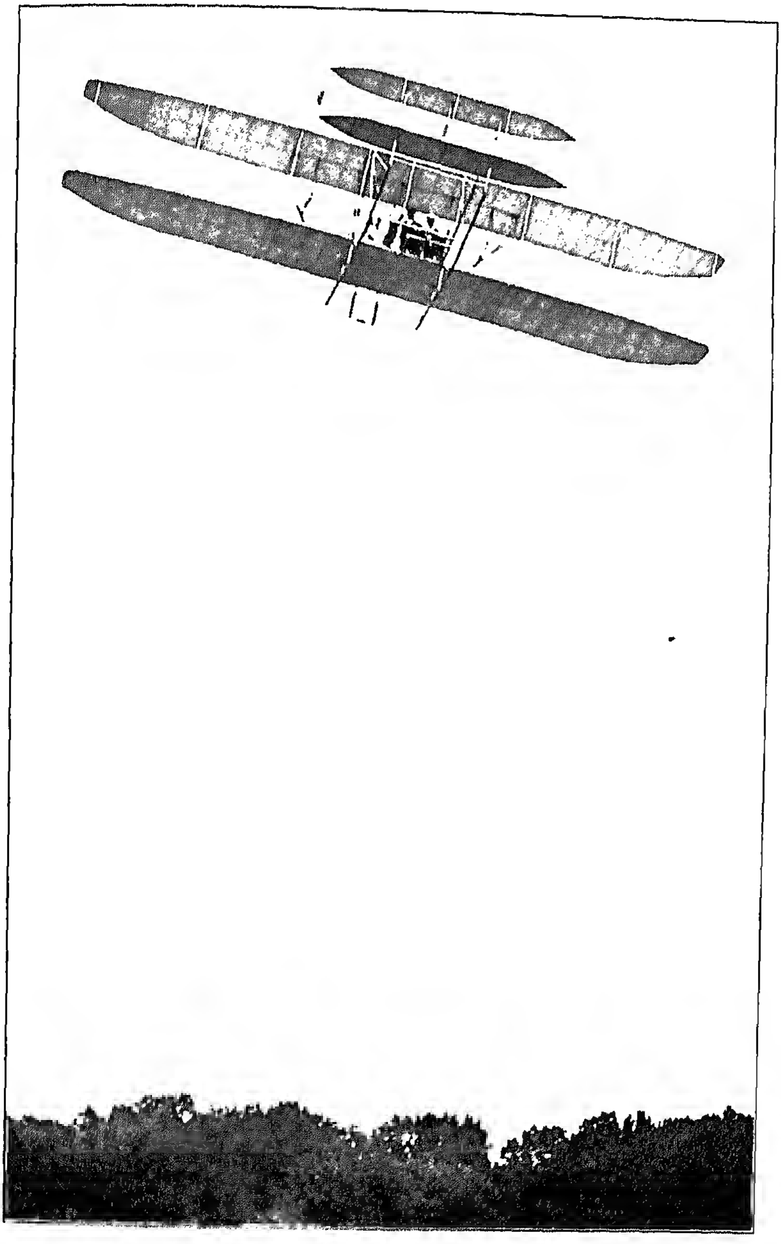


FIG. 23 WRIGHT BROTHERS' AËROPLANE, FORT MYER, VA., SEPTEMBER 12, 1908. ORVILLE WRIGHT AND PASSENGER. TIME, 9 MIN., 6 SEC.

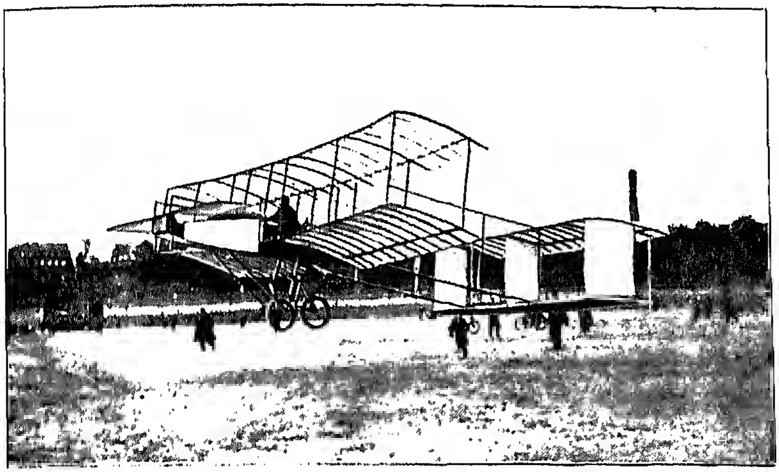


Fig. 24 Farman Aéroplane

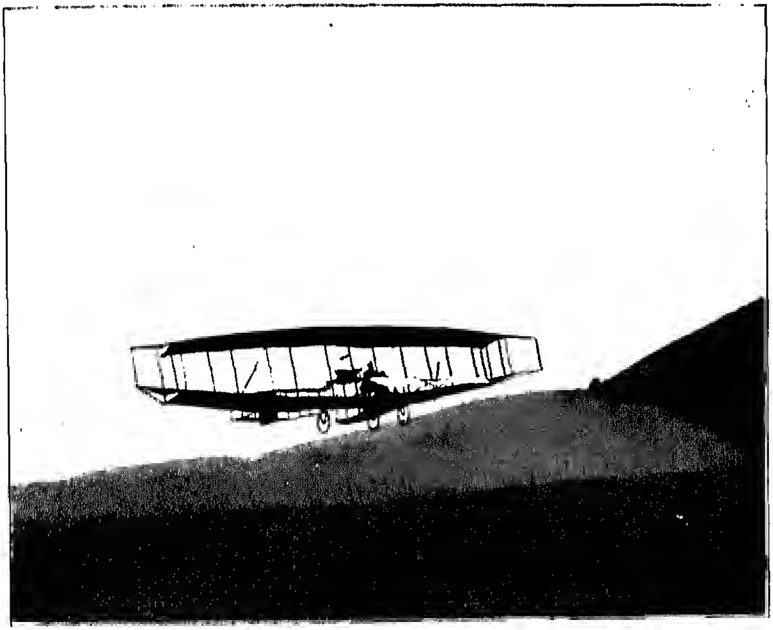


Fig. 25 "June Bug" Aéroplane, Hammondsport, N. Y. Aërial Experiment Association

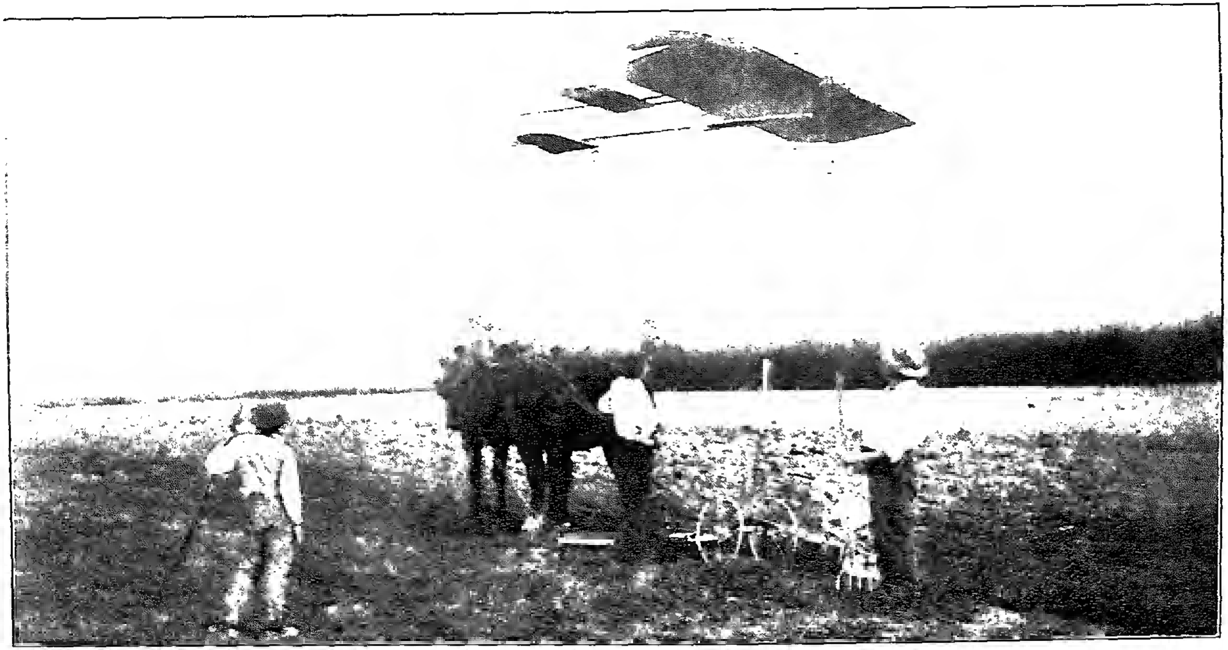
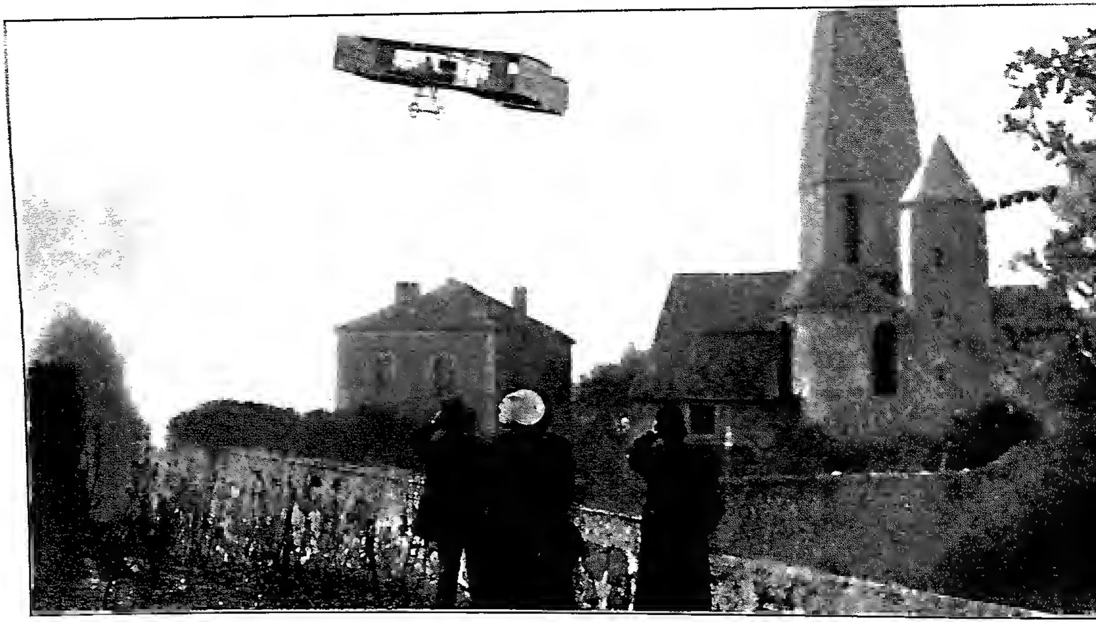


FIG. 26. FROM TOWN TO TOWN BY AËROPLANE. M. BLERIOT PASSING OVER A FARM DURING HIS FLIGHT FROM TOURY TO ARTENAY.



From Town to Town by Aëroplane: Mr. Henry Farman Skirting a Church and Passing Over a Village near Rheims